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INFLUENCE OF POWER ON THE SPIN OF LIGHT PLANES

L. Beaurain

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16. Abstract

Various mock-ups are tested in wind tunnel experiments to study the effect of power on light plane spin with regard to the following propeller parameters: thrust, slipstream, gyroscopic torque and reversal torque. It turns out to be impossible to formulate a general rule for the overall effect of the propeller and hence also for the effect of the separate parameters. However, for right spin, the effect of the motor is either zero or anti-spin, never adverse. There appears to be no correlation between the geometry of certain components of the aircraft and the "overall propeller effect."

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INFLUENCE OF POWER ON THE SPIN OF LIGHT PLANES[1]

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INTRODUCTION

The present report includes the results of studies requested by the S.T.Aé./EG/a [Service Technique de l'Aéronautique -- Technical Aeronautics Agency] in orders: No. 5, Lot No. 1, Contract No. 75.981114 and No. 10, Lot No. 2, Contract No. 76.98221. /4*

These studies involve the effect of power on the spin of light planes. They are a follow-up to a study already done at the I.M.F.L. [Lille Institute of Fluid Mechanics] on a motorized model of the CAP 10 airplane, the results of which were presented in Report No. 1238/VY of Apirl 9, 1976.

1. Overall Comments /5

1.1. Preliminary Remarks

The effect of a rotating propeller on spin has already been studied at the I.M.F.L. on a light plane mock-up. This was the CAP 10 mock-up equipped for the occassion with a two-stroke motor. The aim of this study was limited to defining the overall effect of the power. The results were presented in the I.M.F.L. Report No. 1238/VY of April 9, 1976.

Since these initial results revealed that the power had a certain effect, in order to understand the phenomenon it appeared

[1] Translator's note: The original French is very sketchy in places, with several incomplete sentences. No attempt has been made to edit the French text, and where it is rough or note-like, the English translation reflects this.

* Numbers in the margin indicate pagination in the foreign text.

desirable to determine this or those parameters of the parameters listed below whose effect was the most pronounced. This is the primary objective of the present study. The parameters in question are the following:

-- thrust -- slip stream -- gyroscopic torque -- reversal torque.	of the propeller

Another aim of the study is to motorize other spin mock-ups in order to check to see if the conclusions drawn from the first CAP 10 tests could be generalized. In order to motorize several mock-ups, it was nevertheless essential to make use of one "propeller-motor-feed" system which is at once inexpensive, reliable and easily mounted in any model whatsoever.

Since the two-stroke motor used for the previous CAP 10 study did not meet these demands, a new power system was researched and developed, the characteristics of which will be given in a later section. The conditions of use of this power system are such that it is now easy to study the effect of this parameter, i.e. power, on the spin of any light plane mock-up.

Let us state again that within the scope of the first objective cited above, i.e. the effect of separate parameters, in order to study the effect of thrust and reversal torque we had to develop /6 a system which, in addition, would be perfectly suitable for studying anti-spin rockets like those which have already been made at the I.M.F.L.:

a) Within the scope of a general study (see I.M.F.L. Reports 1009/VY 1 and 2 of July 1973 and December 1974);

b) In the course of a study adapted to a given plane (the HR 200, see I.M.F.L. Report No. 1220/VY of October 4, 1975).

This new device, which is clearly more reliable than the first, is available for all anti-spin rocket studies.

1.2. Presentation of the Report

The report includes five main sections.

The first and second section deals with overall points:

-- mock-ups used
-- devices employed
-- list of tests performed
-- manner of presenting the results
-- various observations.

The second section of the report is devoted to the findings concerned with the separate effects of power such as thrust, slip stream, etc.

The third section is devoted to findings obtained from mock-ups initially used in a general study of spin. These mock-ups were motorized and the tests were limited to determining the overall effect of the rotating propeller.

The results presented in the fourth section of the report are from tests of the same type as the tests discussed in Section 3, but this time the tests are done on two mock-ups of given airplanes.

The fifth section of the report contains the general conclusions.

1.3. Mock-Ups Used /7

Four mock-ups were used for the present study, for one of which various aft fuselage geometries can be obtained.

Mock-up CAP 10: This is a mock-up, which, among others, was already used for the first "motorized" study (see Report No. 1238/VY cited above).

Only this mock-up was used for tests involving the separate effects of the rotating propeller, i.e. thrust, slip stream, etc. For all the other mock-ups, which are discussed below, only the overall effect was investigated.

General study mock-up: This mock-up was used in a general study of light plane spin (see I.M.F.L. Report No. 1240/VY of February 28, 1977).

Remember that this mock-up was designed to be able to represent various fuselage geometries aft of the wings.

Taking into account the findings of study 1240/VY cited above, for the present study three shapes of the aft fuselage frame were retained, namely:

Specific mock-ups of given airplanes: These were two mock-ups which were used in a recent wind tunnel spin study. We have labelled these mock-ups A and B.

It should be pointed out that all of the mock-ups were tested for the present study for a single case of load and with the flaps retracted.

1.4. Devices Employed

In this section we will discuss the various apparatuses used in the study. These are four in number:

-- power unit: to study the overall effect of the rotating propeller;

-- rocket motor: to represent the thrust and reversal torque in succession; /8

-- mass replacing the propeller: to represent the gyroscopic torque;

-- wool thread: to visualize the flow.

<u>1.4.1. Power Unit</u>

Plate 1 shows the power unit installed in the CAP 10 mock-up. All the components of this unit are currently being used in aerodynamic model studies.

The propeller is made of "Top Flite" nylon. Its mass and geometric properties are similar to those of the propeller which we would have built if we wanted to adhere strictly to the specifications for the CAP 10 propeller. During the tests for the present study this propeller showed a great deal of strength when it hit against the net surrounding the test area.

The electric motor is a JUMBO 540 F made by Graupner with the following characteristics:

-- direct current

-- power consumed at 8000 rev/min ≈ 70 watts

-- maximum speed 12,000 rev/min; the speed can be reduced by changing the supply voltage, for example an "airplane" rotation of 2500 rev/min should be represented on the mock-up by a rotation of ≈ 8000 rev/min.

The power for the motor (in order to obtain 8000 rev/min) is provided by five 1.2-volt SAFT batteries with a capacity of 0.45 Amps/hour. These batteries have the following characteristics:

-- They can supply a very high intensity for a low mass;

-- They can maintain a nomimal voltage for a long time;
-- They can be charged very quickly.

While the tests are in progress, the motor can be signaled to stop by a remote control device.

The entire assembly (motor + power supply + receiver) weighs about 0.360 kg. This mass is compatible with that which can be borne by a light plane mock-up, with the understanding of course that certain components contribute to the balance of the mock-up. /9

For a propeller rotation rate of 8000 rev/min, the range of of the batteries is on the order of 2.5 minutes which makes it possible to do about 15 tests with the same set of batteries.

The cost of the power unit and of its installation in a mock-up represents approximately 4% of the total cost of a light plane spin mock-up.

1.4.2. Rocket Motor

Plate 2 shows the rocket motor installed in the CAP 10 mock-up. The motor operates on the following principle: a compressed gas (compressed to the liquid state) in a reservoir is released; it expands in a nozzle (at the end of a semi-rigid tube) at the point on the model where one wants to apply the thrust.

The gas used is Forane 502 of the freon familiy. It was chosen in particular for the following reasons:

-- its high density in the gaseous state (thrust + $f(\rho)$)
-- its relatively low pressure of 8 bars in the liquid state (hence a relatively light reservoir and operating parts such as valves, tubes, etc)
-- its practically zero level of noxiousness within our limits of use.

The reservoir which we used holds 0.110 kg of liquified gas. Under our test conditions the impulse created by the ejection of the gas is ≈ 10 newtons/sec, i.e. a thrust equal to the weight of the mock-up for 1 sec.

The selected value of the thrust modulus is obt[illegible] adjusting the diameter of the collar of the nozzle. [illegible] tests, the maximum thrust value which we [illegible] show was [illegible] newtons. Thus the apparatus allowed the thrust to be applied for ≈ 5 sec, i.e. ≈ 16 sec on the scale of an actual airplane, which is sufficient time to study the effect of this parameter. /10

The gas is released by means of a valve opened by remote control.

The entire unit (motor and accessories + remote control and accessories) weighs 0.400 kg with the reservoir full. To the extent that for a future study, for example the study of an anti-spin rocket, the impulse level is excessive, it is possible to reduce the weight of the loaded system by using a smaller reservoir.

It should be noted that the release of the gas causes a 10% decrease in the mass of the model. This does not cause too much of a problem, to the extent that the reservoir is placed such that its variation in weight does not change the center of gravity and the inertial forces. The tests done with this rocket motor have shown that it is plainly easier to use and more reliable than the gunpowder motor which was previously used at the I.M.F.L. to study anti-spin rockets (see I.M.F.L. Reports 1009 VY-1 and 2 of July 1973 and December 1974). The cost of the new apparatus, which is on the same order of magnitude as that of the power system described under heading 1.4.1., is clearly less than that of the gunpowder motor.

1.4.3. Mass Replacing the Propeller

In order to represent the gyroscopic torque of the propeller, we replaced the latter by a metallic disk 4 cm in diameter and with the same moment of inertia as the propeller, i.e. at full aircraft scale: 0.64 m^2kg.

The disk is driven by the motor described under heading 1.4.1.

1.4.4. Wool Thread

The visualization tests were done with the CAP 10 mock-up mounted on a turning arm in the vertical wind tunnel. The turning arm used is that which was used to measure spin rotation coefficients (Report No. 1138/VY of March 1975). With this arm it is possible to apply a spin of selected characteristics to the mock-up. The spin characteristics include rotation rate, longitude and latitude, transverse attitude, etc. However, the present arm cannot be mounted with cameras turning with the mock-up and this would have been desirable.

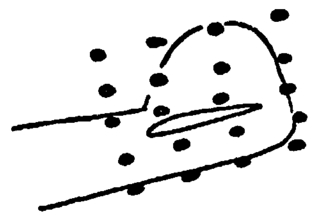
The wool thread observations were made under the following test conditions: /11

1) Without rotation of the mock-up
   - -- with and without wind tunnel wind
   - -- with the propeller stopped or rotating.

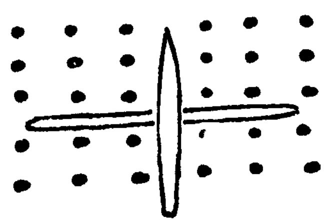
Observation of the wandering wool thread in the vertical planes located 0.7 m (airplane) from the symmetry plane on each side of the fuselage aft of the wings. The wool thread is photographed.

2) With spin rotation
   -- with wind tunnel wind
   -- with propeller stopped or rotating.

Twenty wool threads attached to the mock-up in the vertical planes cited above were arranged according to the following diagram.



The wool threads are photographed by a camera fixed outside of the stream and the plane back of the films gives the position of the threads at each half revolution (left, right). It is understood that for the tests with the propeller rotating, the two directions of spin rotation are applied to the mock-up in succession.



The same type of test was then done but with the wool threads placed in a plane perpendicular to the plane of symmetry and containing the leading edge of the horizontal stabilizers.

1.5. List of Tests Performed

1.5.1. Free Spin

For the free spin tests, about 230 mock-up launches were done. These launches are divided into the following different types of tests:

1.5.1.1. CAP 10 Mock-Up /12

1.5.1.1.1. Overall Motor Effect

To begin with, we re-did a series of tests which had already been done on the CAP 10 mock-up, in this case to check the overall effect of the motor. These tests had a double purpose:

1) Verification tests necessary to determine the condition of the mock-up; in fact, prior to the present study, the mock-up had been subjected to a very large number of launchings, on the order of 800, in the course of various studies.

2) To test the new power unit.

These tests were done under the following conditions:

-- power parameters:
  a) propeller stopped then rotating at about 2500 rev/min (airplane value), which thus represents a high speed;
  b) motor axis parallel to the plane of symmetry then inclined (as in certain airplanes) 5° to the right.

-- control surfaces:
  study of 15 control surface deflection combinations, i.e.:

Rudder	Elevator	Ailerons
With	Nose-up Neutral Nose-down	Against then with Neutral Against then with
Neutral	Same as above	Same as above
Against	Same as above	Same as above

-- for the "with motor" tests, a study of right and left spins.

1.5.1.1.2. Thrust Representation /13

The value of the thrust of the propeller was measured on a gauge balance in the wind and at a spin angle. The value which we have then posted represents a thrust of about 1500 newtons for the airplane, which corresponds to a high motor speed.

Spin study of 15 control surface deflection cmobinations mentioned above: these tests were essentially for right spin. Only a few tests were done with left spin to check certain findings with right spin.

1.5.1.1.3. Reversal Torque Representation

The reversal torque value, which is determined from measurements with the balance, represents about 400 newtons-meter for the airplane. This value likewise corresponds to a high engine speed.

To study the reversal torque effect, 15 control surface deflection combinations were investigated, both for right spin and for left spin.

1.5.1.1.4. Gyroscopic Torque Representation

Test program identical to that described under 1.5.1.1.3.

1.5.1.2. General Study Mock-Up

Only the overall power effect was studied using the "general study" mock-ups.

For each of the three aft fuselage shapes ( , , ) we studied phenomena obtained with 15 control surface deflection combinations, both for right and left spin:

-- motor axis parallel to the plane of symmetry,

-- propeller rotation rate, 2500 rev/min (airplane).

In addition, for the  shape, some tests were done with the motorized mock-up with the vertical stabilizer removed. This point will be discussed in the section devoted to the findings of this series of tests.

1.5.1.3. Mock-Ups A and B /14

The study of these mock-ups was very brief and limited to the following tests:

Propeller rotating at 2500 rev/min: study of right and left phenomena for two control surface combinations, one pro-spin and the other pro-recovery.

1.5.2. Visualization Tests

Spin characteristics apply to the mock-ups mounted on the turning arm:

-- two longitudinal latitudes: $/\theta/ = 30°$ (spin slightly nose-down) and $/\theta/ = 60°$ (nose-down spin)

-- horizontal span

-- duration of one revolution for a full-scale airplane: 2 seconds

-- radius zero

-- wind speed in the wind tunnel 11 m/sec, which represents a descent speed of 35 m/sec for the airplane.

Power parameters:

-- propeller non-rotating and rotating (2500 rev/min)

-- motor axis parallel to the plane of symmetry.

1.6. Presentation of the Results

Nearly all of the results of the present study are given in the form of tables or graphs in the plates found at the end of the report.

1.6.1. CAP 10 Mock-Up Results

Plates 3, 5, 7, 9 and 11 are of the same type. A plate of this type is concerned with the effect of a motor parameter. It organizes the results obtained according to the various control surface deflection combinations, the left and right "motorized" spin and the shape of the air frame. The manner of presenting the results in these plates is that which is often used by us for spin tests. The last plate (Plate 23) summarizes the main points of the presentation method. Unfolded, this plate can be consulted simultaneously along with any other plate of results.

The following plates concern these effects: /15

3	Overall	effect	of the motor (non-inclined)
5	"	"	of thrust
7	"	"	of reversal torque
9	"	"	of gyroscopic torque
11	"	"	of the inclined motor.

Some of the results included in these plates are given again in more detail in Plates 4, 6, 8, 10 and 12. These plates are concerned with perfectly stabilized spins (at least in air frame configuration). They show in detail the effect of such and such a motor parameter on the principle characteristics of the spin, namely:

-- longitudinal attitude
-- transverse attitude
-- duration of one revolution of spin
-- spin radius.

Thus in one plate we find:

	Left	Center	Right
The characteristics of the spin	"motorized" left	glider	"motorized" right

The following plates concern these effects:

4	Overall	effect	of the motor (non-inclined)
6	"	"	of thrust
8	"	"	of reversal torque
10	"	"	of gyroscopic torque
12	"	"	of the inclined motor.

The following plates (13-18) concern the visualization tests. These plates give the position of the wool thread for various test configurations.

1.6.2. General Study Mock-Up Results

The results obtained with these mock-ups are included in Plates 19 and 20.

Plate 19, according to a presentation identical to the presentation of results in Plates, 3, 5, etc. for CAP 10, organizes the results of the tests with and without power for three fuselage shapes:  ,  and  . /16

In Plate 20 we give the result of a few tests done with the  mock-up without the vertical stabilizer.

1.6.3. A and B Mock-Up Results

The results (there are fewer of them) obtained for mock-ups A and B are given in Plate 21.

1.6.4. Results of All the Mock-Ups

Plate 22, by organizing the main results with regard to the overall effect of the motor found for all the mock-ups, makes it easier to come to a conclusion on the effect of this parameter.

1.7. Various Observations

Before going on to the results, it is worthwhile to remember or point out certain points.

-- Rudder and ailerons are said to be "with" or "against" when these control surfaces are deflected for or against a turn in the same direction as the spin.

-- All of the values, both in the text and in the plates, are given on a scale for the full-sized airplane.

-- As for the separate motor parameter, in order to better reveal their effect, we have systematically represented a value of each parameter corresponding to the airplane at a high engine speed.

-- In Plates 4, 6, 8, etc. in the center of the plates, we have included the right and left CAP 10 glider spin characteristics. In principle, these characteristics should not be influenced by the direction of the rotation, but this is not always the case. This deviation should be attributed to the condition of the mock-up which, we recall, prior to the present study had been the object of numerous studies. However, it should be pointed out that this difference is not too bothersome to the extent that in order to determine the effect of such and such a parameter on the spin in one direction the glider spin in the same direction is taken as a base of comparison.

2. CAP 10 Mock-Up Results /17

2.1. Preliminary Remarks

In this section of the report, the results will be described according to the following plan:

- -- CAP 10 "glider" spin
- -- CAP 10 "motorized" spin (overall effect)

Review of results included in previous reports with possible details contributed by the present study.

- -- thrust effect
- -- reversal torque effect
- -- gyroscopic torque effect
- -- effect of inclining the motor
- -- slip stream effect

2.2. CAP 10 "Glider" Spin

See middle column of the charts in Plates 3, 5, 7, 9, and 11.

Briefly let us review the main findings obtained with the non-motorized CAP 10 mock-up:

- -- spins which are often:
  - -- calm
  - -- slightly to moderately nose-down:
  - -- $/\theta/ \geq 30°$
  - -- leading wing slightly down
  - -- moderately rapid: 2 sec/rev
  - -- tight (spin radius $\leq$ 1 m)

Depending on the deflection of the control surfaces

-- sometimes:

-- more nose-down, leading wing high and rotating irregularly

Depending on the deflection of the control surfaces

The spin is maintained in a range of control surfaces which is approximately equal to one-half of the total range. /18

The preponderant control surface for CAP 10 spin is the rudder:

-- rudder "with": spins often maintained

-- rudder "against": stoppage in all cases (in 1 to 2-1/2 revolutions, depending on the position of the other control surfaces.

2.3. Overall Effect of the Motor

See Plates 3 and 4.

If, in order to determine the effect of the rotating propeller on CAP 10 spin, we limited our observations to:

-- the range of the control surfaces where the spin is maintained and

-- the respective effect of each control surface (hence the operating procedures),

we would conclude that the effect of the "motor" paramter is practically null (see Plate 3).

In fact, in order to reveal the effect of this parameter, we must further analyze the results, in particular by taking into consideration the characteristics of spin and recovery. The effect of the motor is then manifested in the following way:

With respect to air frame shape

Left spin	Right spin	See Plate
The stationary spins are often less nose-down	The stationary spins are more nose-down	
Sometimes slower	On average, also rapid	4
Sometimes tight (larger spin radius)	Less tight	
Leading wing rises	Leading wing drops	
The recoveries are longer because the spins are less nose-down	The recoveries are faster because the spins are more nose-down	3 Lower blocks

As for the nature of the stationary spin, the above remarks already give an initial idea of the effect of separate parameters of the rotating propeller. /19

Thus when a spin characteristic changes in one direction or the other, depending on the direction of the spin, one can imagine that this involved a torque effect or perhaps as well a slip stream effect. By contrast, when a characteristic always changes in the same direction, whatever the spin direction (this is the case for the spin radius), a thrust effect can be imagined. We will come back to these points in the following sections.

Recall that the results which have just been presented (or which are about to be presented) correspond to a high engine speed, which is a necessary condition in order for the effect of the motor to be sufficiently pronounced at least for the CAP 10 (see Report No. 1238/VY).

Following the results concerning the overall effect of the rotating propeller and before going on to the study of "separate" motor parameters, we might state the following hypothesis:

Since the overall effect of the motor is only moderate, if not weak, the effect of each separate parameter would also be weak, unless the effect of two parameters is large but in different directions.

2.4. Thrust Effect

See Plates 5 and 6.

The blocks of findings included in Plate 5 show that the effect of the propeller thrust is not very large on all of the phenomena, especially on the range of spins and recoveries.

We can note only two control surface combinations for which the "glider" and "with thrust" phenomena are relatively drawn out, namely rudder "neutral" and ailerons "against":

When the control column is	Glider configuration	With thrust	Hence the effect of thrust
Pulled back	Absolute stoppage of the spin	Doubtful recovery	Pro-spin
Pushed forward	Spin well maintained	Possible stoppage	Anti-spin

When the rudder is deflected for the recovery, the pull-out /20 is often slightly quicker when the thrust is represented.

If we examine the spin characteristics (Plate 6) we find that going from the "glider" configuration to the "with thrust" configuration:

-- causes little change in the longitudinal and transverse attitude

-- sometimes slows down the spin

-- widens the spin (the radius increases).

From these observations we can thus conclude that when the power (overall effect) effects the longitudinal and transverse attitude this effect cannot be attributed to the thrust. By contrast, this parameter seems to be the cause of widening the spin. With regard to the spin, we can also note that the effect of the thrust is, a priori surprizing, since the effect of a force (the thrust) directed towards the front of the mock-up is to cause the mock-up to move back with respect to the spin axis.

This phenomenon can be explained in the following way: in the new equilibrium of forces during the spin, the contribution of the thrust, which is centripetal, must be compensated for and this will be done in large part (bearing in mind that these are very nose-down spins) by an increase in the centrifugal force. If the rotation rate is changed only slightly, the increase in the centrifugal force can then only be obtained by increasing the spin radius.

2.5. Reversal Torque Effect

See Plates 7 and 8.

From the results included in Plate 7 we can first of all note that the reversal torque:

- -- does not affect the number of stationary spins,
- -- does not have a regular effect on the recovery times.

As for the stationary spin characteristics (see Plate 8), the act of representing the reversal torque:

- -- on average causes nose-up left spin and nose-down right spin,
- -- has no systematic effect on the transverse attitude, /21
- -- only rarely effects the duration of one revolution.

Thus the reversal torque effect for the CAP 10 is not very large. We will only note that in going from the "glider" configuration to the "with motor - overall effect" configuration, the longitudinal attitude of the spin is changed and this change is due in part to the reversal torque.

Note: *A priori* we could imagine that a reversal torque affects the spin like the ailerons might affect it. But if we compare the test results in which on the one hand the deflection of the ailerons causes such a wing to drop and on the other hand the frame causes the same wing to drop, we do not arrive at the same conclusion with regard to the main characteristics of the maintained spin. This difference must probably be explained by the fact that the frame acts only in a role, which is not the case for the ailerons, during spin.

2.6. Gyroscopic Torque Effect

See Plates 9 and 10.

As the results of Plates 9 and 10 show, the gyroscopic torque effect is practically zero. In particular, the main spin characteristics (Plate 10) are hardly affected when we represent the torque using the "glider" case.

By calculation, it is possible to determine the pitching moment (right nose-down, left nose-up) due to the gyroscopic effect and to locate this moment with respect to the overall aerodynamic pitching moment during a stabilized spin. This calculation gives:

$$\frac{\text{"gyroscopic" moment}}{\text{"overall" moment}} \approx 0.08$$

The "gyroscopic" moment is thus slight but nevertheless not negligible.

During the "overall motor effect" we observed a tendency to dive to the right and pull up to the left. A priori it might have seemed logical to attribute this tendency to the gyroscopic torque. But it happens that the separate study of this parameter did not confirm this assumption.

In Report TN 3480, dating back about 20 years, NASA studied the gyroscopic torque effect. According to their tests, which were similar to ours, it turns out that the effect of this parameter is small. Only sometimes is an adverse effect of the torque found for the recovery of a right spin. Thus the spin, although more nose-down than in the glider configuration, is more difficult to control and this seems to be due to an increase in the rotation rate. /22

It should be pointed out that these findings were obtained using a mock-up of a military plane whose mass and geometric characteristics are rather dissimilar from those of our mock-ups. In addition, in these tests several load conditions were tested and the gyroscopic torque effect turned out to be sensitive to this parameter. Furthermore, certain spins of the US mock-up were oscillatory, which is not the case in our tests. Under these conditions, any comparision between the US findings and our findings turns out to be a delicate matter. It can only be concluded both with respect to the NASA study and the I.M.F.L. study that the gyroscopic effect did not appear to be fundamental.

2.7. Overall Effect of the Inclined Motor

See Plates 11 and 12.

By representing the motor axis non-parallel to the plane of symmetry, we reproduced the conditions found in certain airplanes. Tests of this kind had already been done during the first motorized CAP 10 study (Report 1238/VY), but with the motor set at a small angle of 2°, whereas for the present study we set this angle at 5°.

As the results of Plates 11 and 12 show, the effect of the motor in an inclined position turns out to be negligible. This shows up particularly in the spin characteristics of Plate 11 where it is not possible to formulate a rule for the effect of this parameter with respect to longitudinal and transverse attitude and to the rotation rate. Only the spin radius increases in a regular way, both to the left and to the right. This observation confirms the effect of the thrust discussed above.

Thus the overall effect (pro-spin or anti-spin depending on the direction of the rotation) found when the motor axis is in the plane of symmetry disappears when the motor is inclined by 5°. This can be explained by the yaw component which is introduced by inclining the motor. Let us clarify this remark:

The thrust force in our tests represents 1500 newtons for the airplane. The yaw component of the motor for an inclination /23
of 5° is thus on the order of 130 newtons, which corresponds to approximately 2% of the weight of the airplane. This is a low value, but in the course of previous studies concerning anti-spin rockets (I.M.F.L. Report 1009/VY) we saw that the effect of rockets acting in a yaw situation is very pronounced. Thus a small yaw component might be very liable to counter an effect (a smaller effect of course) in the opposite direction.

In the present case, for righ- spin, we thus have:

a) Motor axis in the plane of symmetry: anti-spin effect of the power;
b) Inclined motor axis: power has zero effect because in this case the motor (inclined towards the right) creates a pro-spin yaw component.

and conversely for a spin to the left

Inclining the motor thus cancels the power effect.

2.8. Slip Stream Effect

See Plates 13-18.

It should be pointed out that the tests done for the purpose of obtaining data on the slip stream effect were essentially limited to wool thread observations in the region obviously most interesting to study, namely around the horizontal stabilizers and the vertical stabilizer.

From films, we have kept a few tests which are presented graphically in Plates 13-18. As will be seen below, these tests provide only partial information.

The initial data obtained was taken from tests without and then with the motor, but without spin rotation (Plates 13 and 14). From these tests it appeared that the slip stream was thrown back above the mock-up by the wind and because of this did not reach the horizontal stabilizers. Compare for example in Plates 13 and 14 the graphs on the left (without motor) with the graphs (with motor). Subsequent tests with the mock-up in rotation never invalidated this finding. See Plates 15-18, compare graphs on the left (motor stopped) and graphs on the right (with motor).

We know that the overall effect of the propeller on the CAP 10 spin is at most moderate. We have likewise seem in the above sections that the respective effect of separate parameters /24 is non-existent or small. In the present case, the effect of the slip stream can also only be small. Under these conditions it is normal that the qualitative visualization tests can only supply limited information. Insofar as a quantitative study would prove to be useful, it would have to call upon measurements of moments or pressures not only on the horizontal stabilizers but also on the aft fuselage and certain regions of the wings.

2.9. Conclusion

The study of the various separate parameters:

- -- thrust
- -- slip stream
- -- reversal torque
- -- gyroscopic torque

of the rotating propeller for the CAP 10 mock-up did not reveal a large effect for any of these parameters. This is not in disagreement with the overall effect of the propeller, since this effect likewise appeared to be small.

For the CAP 10, the overall effect can be considered as being primarily the consequence of:

-- thrust: this parameter widens the spin;

-- reversal torque, which, on average, "flattens" the spin to the left and causes the spin to the right to dive.

The present study likewise showed that an overall effect of the propeller, with its axis in the plane of symmetry, can disappear if the motor axis is no longer in this plane. The reason is that in this last case the propeller has a partial yaw action.

Let us end by pointing out that the present conclusion concerns only the CAP 10 tests. Results which are going to be presented in the rest of the report will show that the effects (either "overall" or "separate") of the propeller cannot be generalized.

3. Results Obtained with "General Study" Mock-Ups /25

3.1. Preliminary Remarks

Within the scope of the investigations of the present study, it was intended to motorize other mock-ups than the CAP 10 mock-up in order, first of all, to increase the amount of data on the motor effect and, secondly, to test the new power system.

First of all, we motorized a "general study" mock-up, whose stationary components can be put together so as to represent various geometries of the aft fuselage. Of these geometries, we have three for which the spin findings are very different. The following table specifies these geometries and summarizes the results:

Aft fuselage shape	Results	See Report No. 1240/VY Plate 4
Square □	Spin (often slightly nose-down) maintained in approximately half of the range of the control surfaces	First column of blocks
Flat on the bottom, rounded on top 	Flat spin maintained throughout the entire range of the control surfaces	Seventh column of blocks
Rounded on the bottom, flat on top 	Nose-down spin obtained in a very small range of the control surfaces	Tenth column of blocks

A few launchings with the □ motorized mock-up minus its vertical stabilizer have just been added to the above three series of tests. The purpose of these tests will be discussed in detail under heading 3.5 which deals with the findings.

In the next four sub-sections we will describe the effect of the rotating propeller on the spin of the □ mock-up, then

, then the and finally the □ minus the vertical stabilizer.

3.2. Power Effect, □ /26

See Plate 19, the first three columns of blocks.

The rotating propeller has a very appreciable effect on the mock-up. This is an anti-spin effect which is manifested for both directions of spin rotation.

Left Spin

The nature of the maintained spin is little affected by the power. Only a few "with motor" spins are less nose-down than the glider spins.

The effect of the motor is especially visible when the rudder is deflected for recovery. In effect, in this case, in "glider" configuration, the spin is maintained if in addition, the ailerons are "against." For this same cmobination of control surfaces, the spin stops in the motorized setup.

See Plate 19, compare first and second column of blocks

Right spin

The effect of the motor is very pronounced and it appears in three instances:

a) Rudder "with" + ailerons "against," the spins, which are flat in the glider setup, become nose-down with the motor.

b) Certain stationary or long-lasting spins (rudder "with") give way to rapid recoveries.

c) Stationary or long-lasting spins (rudder"against") for the glider mock-up always stop rapidly with the motor.

See Plate 19, compare third and second columns of blocks

Thus the effect of the motor for the □ mock-up is to increase the chances of recovery, both for left and right spin, but this is more clearly the case for right spin. And, since the effect is in the same direction for both spin directions, we can deduce from this that among the "separate" parameters, the thrust is largely responsible for this, but not entirely since the left and right results are not identical.

A partial conclusion now asserts itself: between the results /27 for the "motorized" CAP 10 mock-up and the □ mock-up, there are at least three points on which the conclusions vary. These are:

-- Modulus of the (overall) propeller effect;
-- The way in which this effect is manifested;
-- Effect of pure thrust.

3.3. Power Effect, ⌓

See Plate 19, the three central columns of blocks.

Comparison of the results for the □ and ⌓ motorized mock-ups leads to certain conclusions which, qualitatively, are identical for the two geometries. In fact, for the ⌓ we find:

-- an anti-spin effect of the motor, no matter what the spin direction, nevertheless with:

-- an effect which is clearly more pronounced for right spin.

The anti-spin effect can be figured out by the number of stationary spins obtained for the different pieces:

left spin: 9 spins glider setup: 10 spins right spin: 4 spins	for 10 control surface combinations

for these maintained spins we also note that they are:

-- slightly flatter for left spin -- less flat for right spin	than in the glider setup.

In conclusion, the power effect found for the  mock-up is on the whole quite pronounced, but less than it was for the  mock-up. By contrast, it was appreciably more pronounced than for the CAP 10 mock-up.

3.4. Power Effect,  Mock-Up

See Plate 19, three right hand columns.

The effect of the rotating propeller on the spin of the  mock-up is small or at most moderate. Let us remember that for this mock-up the "glider" spins, which are always nose-down, are only maintained in a very small range of the control surfaces.

The effect of motorizing this model is: /28

-- to the left, to flatten the spin by about 15° and increase, though moderately, the range of the control surfaces in which the spin is maintained;

-- to the right, to cause the spin to dive from 10° to 15° without changing the number of stationary spins (at least within the limits of the control surface combinations which we tested).

The effect (pro-spin to the left and anti-spin to the right) is manifested, among other things, also when the control surfaces are deflected for pull-out, since with the rudder in the "against" position, the recovery takes place on average in:

1-1/2 rev to the left, starting with a spin of $/\theta/ \approx 45°$
3/4 rev for the glider setup
< 1/2 rev to the right, starting with a spin with $/\theta/ \approx 70°$.

In conclusion, the effect of the rotating propeller on the  mock-up more closely resembles that found for the CAP 10 mock-up than that for the  and  mock-ups. This is for two reasons:

a) Relatively small effect and,
b) Variable direction depending on the direction of the spin.

3.5. Tests Without Vertical Stabilizer

See Plate 20.

In the course of study 1240/VY cited above, we did a few tests with a "general study" mock-up with the vertical stabilizer removed. All data on the main point investigated during these tests and the results obtained are given in section 2.6 of Report 1240/VY. Here we note only that the effect of removing the vertical stabilizer was often to cause the spin to dive and thus faciliate the recovery.

Given these results, which were at least unexpected, it seemed interesting to study the effect of the motor under these test conditions.

In view of the results included in Plate 20, it appears that the effects of the power parameter on the mock-up without the vertical stabilizer is as follows:

-- pro-spin to the left
-- little or no effect to the right

} See Plate 20, lower blocks

If we compare these results with those of the complete mock-up, the effect of the motor is thus not the same, since it was anti-spin in both spin directions.

Finally, if we compare the "motorized" results with and without the vertical stabilizer to those for the glider, we find that the effect of removing the vertical atabilizer is pro-spin in both spin directions, while for the glider setup, removing the vertical stabilizer promoted the recovery. /29

The results are summarized in the following table:

Complete glider mock-ups	a)	With power	Anti-spin effect in both directions
	b)	Vertical stabilizer removed	Anti-spin effect
	a + b	Pro-spin effect to the left anti-spin effect to the right	

It is not obvious what conclusion should be drawn from these findings. It seems that the effect of the "separate" power parameters, such as thrust, torque, etc., varies depending on the case studied. Thus for

a) there is a preponderant thrust effect,

a + b) preponderant torque effect.

3.6. Conclusion

If, to the results which have just been presented, we add those for the CAP 10, we can draw the following main conclusions from these collective findings:

1) The modulus of the rotating propeller effect can vary largely from one mock-up to another.

2) The direction of the effect can likewise vary depending on the mock-up studied. This is only valid, however, for left spin.

3) For certain mock-ups, the effect of the rotating propeller is in the same direction for both directions of spin rotation. This implies that among the "separate" propeller parameters, such as thrust, torque, slip stream, etc., the thrust is predominant.

4) For the mock-ups in which the propeller effect varies with the direction of the spin, this effect must be attributed to another separate parameter: torque or slip stream.

5) For a mock-up on which it is possible to change the geometry of the aft fuselage frame, the motor effect varies (especially for the modulus) with this geometry. This might suggest that the propeller has a slip stream effect on the aft fuselage. /30

If from all of the results we try to formulate some general rules, we find that:

a) For right spin, the effect of the motor is either existent or non-existent, and when it exists it is always in the same direction, i.e. promoting the recovery which is therefore a generalization of the rule in question;

b) For left spin, depending on the test conditions, the motor has a beneficial or adverse effect on the spin, hence it is impossible to formulate a general rule in this case.

4. Results for Mock-Ups A and B

/31

4.1. Preliminary Remarks

We finished up the tests of the present study with a small number of specific aircraft mock-ups which we had motorized. The first objective of these tests was, of course, to increase the amount of data on the motor effect. But in addition these tests could possibly provide interesting data on the spin, especially for plane A. We will give details on this point.

During the flight tests of airplane A, an unusual spin for this airplane was obtained. The spin was flat and rapid, to the left initially with power and then with the power cut off. The result of this test revealed the advantage of studying on mock-up A the power effect with respect to flat, rapid spin.

The results for the motorized mock-ups A and B are covered in the two following sub-sections. At this point it should be pointed out that both mock-ups had certain test conditions in common:

-- glider tests followed by motorized tests, left and right spin, and this for:

-- two control surface deflection combinations, one pro-spin and the other pro-recovery.

4.2. Mock-Up A Results

See Plate 21, blocks on the left and lower graph.

The rotating propeller has an effect on the spin of mock-up A, the modulus and direction of which vary depending on the direction of the spin:

-- clearly pronounced pro-spin effect to the left;

-- small anti-spin effect to the right.

In particular the effect on the left spin is as follows:

The spin, nose-down ($/\theta/ = 55°$) for the glider setup, becomes flat ($/\theta/ \approx 20°$) under the effect of the motor.

The recovery from the glider spin requires less than one revolution, whereas in the case of the flat spin, five revolutions are required. /32

The lower graph in Plate 20 provides other details on the power effect with respect to flat spin. Thus if this type of spin is applied at the launch, with control surfaces pro-spin:

a) in right spin (of course with the motor) mock-up A rapidly leaves this spin. In three revolutions it attains a flat spin;

b) in the glider setup the change from flat spin to nose-down spin still exists, but it takes place without agitation (nose-down spin is attained in ≈ 10 revolutions);

c) in left spin the mock-up remains in flat spin.

In this instance the effect of the rotating propeller thus turned out to be very pronounced, both for right and left spin.

It should be pointed out that for airplane A the flat spin was obtained to the left with the motor initially running. From tests on motorized mock-up A, it turns out that these conditions could only be favorable for obtaining this type of spin. From wind tunnel tests, it likewise appears that in right spin with the motor -- even if by means of aerodynamics at the beginning of the pheonomenon the airplane had attained a phase of flat, rapid spin due to the power and without any other means whatsoever -- the flat spin would not be maintained (as long as, of course, the power is not cut off).

The data that they provided within the scope of the general study, the tests on mock-up A also supply interesting data on the spin of plane A itself. To come back to a general conclusion, these tests also showed that it would be desirable for the motor to be included among the parameters usually investigated in a wind tunnel spin study.

4.3. Mock-Up B Results

See Plate 21, results on the right.

The effect of the rotating propeller is not very pronounced. With respect to the glider setup the spin to the left is a little less nose-down, hence the recovery a little less rapid, and conversely for the spin to the right.

/33

From the small number of tests which were done on the motorized mock-up B it seems that plane B can be classified along with those airplanes for which the spin is not very affected by the power.

4.4. Conclusion

In the first place, the present phase of tests allowed us to obtain information on the power effect with respect to the spin of certain existing airplanes.

In the second place, within the scope of the general study, following this series of tests certain observations or conclusions already stated above are confirmed. In particular these are:

-- effect of the motor, the modulus of which varies depending on the airplane;

-- in right spin, if the effect is not zero, it is always in the same direction.

5. General Conclusion /34

5.1. Overall Effect of the Propeller

Plate 22 lists the main results concerning the overall effect of the propeller. From this plate we can draw the following conclusions:

1) For left spin the results vary considerably. Among other things, the effect of the motor can vary from one mock-up to another. Therefore it is not possible to specify an operating procedure with regard to the motor which can be applied in general for spin recovery in all airplanes.

2) For right spin the effect of the motor is either zero or anti-spin. It is never adverse. Thus the "give power" maneuver can be added to the operating procedures concerning the control surfaces for spin recovery.

3) With respect to recovery, the power effect is in all cases more favorable to the right than to the left.

4) If we analyze the "overall propeller effect" results as a function of the geometry of certain components of the aircraft, there seems to be no correlation between the two parameters. Thus, for example, for two aft fuselages of the same type (on the one hand the CAP 10 and on the other the general study mock-up ), the power effect is different.

5) The same is true if the effect of the power is studied as a function of the type of spin (flat or nose-down).

5.2. Effect of Separate Parameters

It is impossible to formulate a general rule for the overall effect of the propeller. Consequently it is also impossible to formulate a general rule for the separate effects of the propeller.

With regard to the thrust (which acts identically for both directions of spin), its effect can be predominant, and in this case it promotes recovery. But in several cases the effect of the thrust is secondary.

In the case where the overall effect of the propeller changes direction with the spin direction, it must be concluded that one effect is predominant, either of reversal or gyroscopic torque or of the slip stream.

The overall effect of the motor can be influenced by the angle which the motor axis makes with the plane of symmetry. In this case the parameter which is especially involved is the yaw component of the thrust. /35

With regard to the CAP 10, the detailed study of various separate parameters did not reveal any significant influence for any of the parameters studied.

5.3. Foreign Findings

In the NASA Report TN D-6575 of December 1971 on the effect of very diverse parameters on spin, one section deals with the effect of the motor. Among other things, it notes:

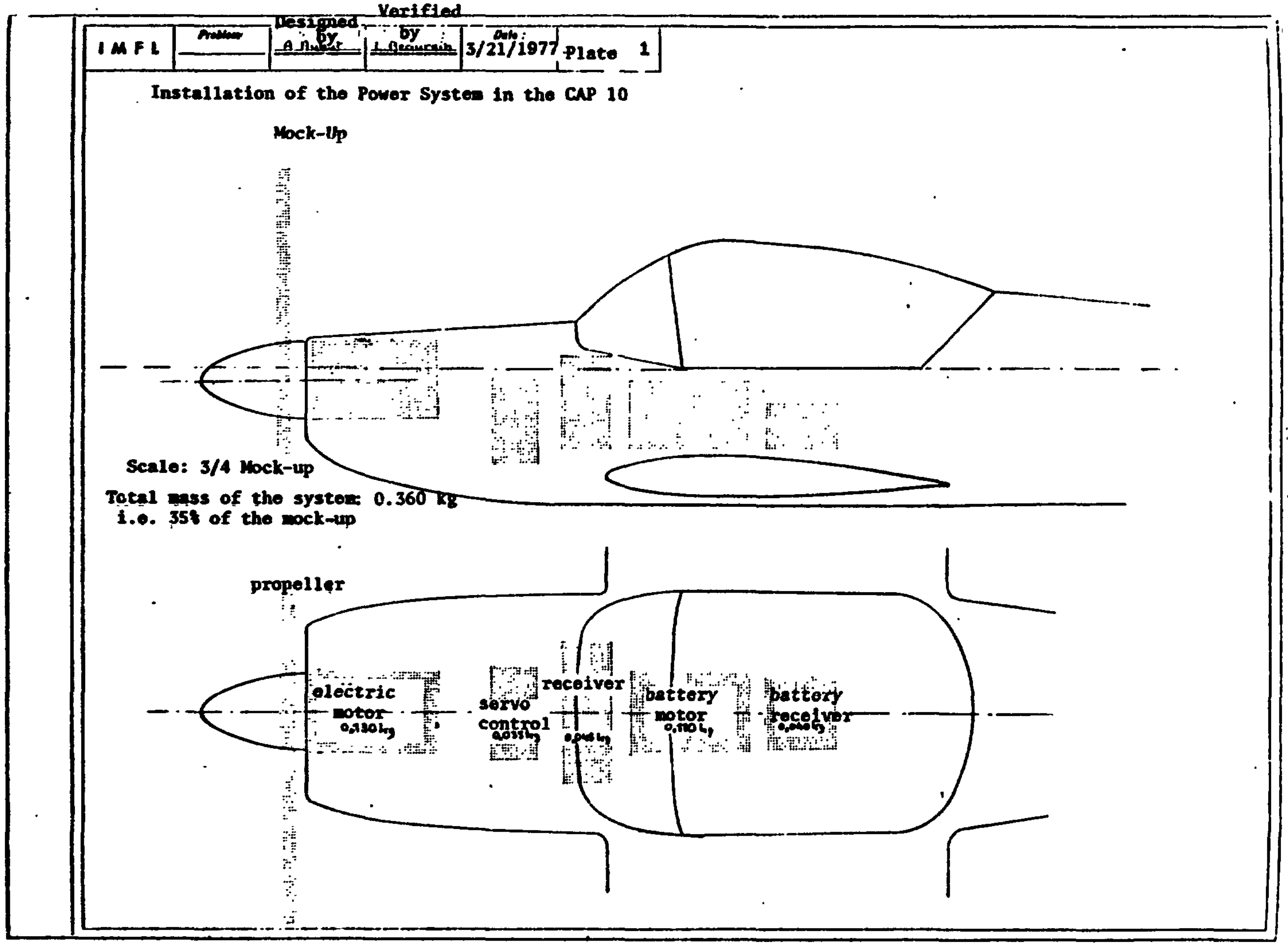
a) a variation in the results ranging from "decisive help from the motor for recovery" to "adverse effect";

b) during the tests, which were few in number and the aim of which was to investigate the effect of the motor, this parameter did not turn out to be very influential except if the axis of the motor was inclined with respect to the plane of symmetry.

NASA concluded that: "Since the effect of the motor can be adverse and unpredictable, it is generally recommended to leave the motor shut off or slowed down during the spin."

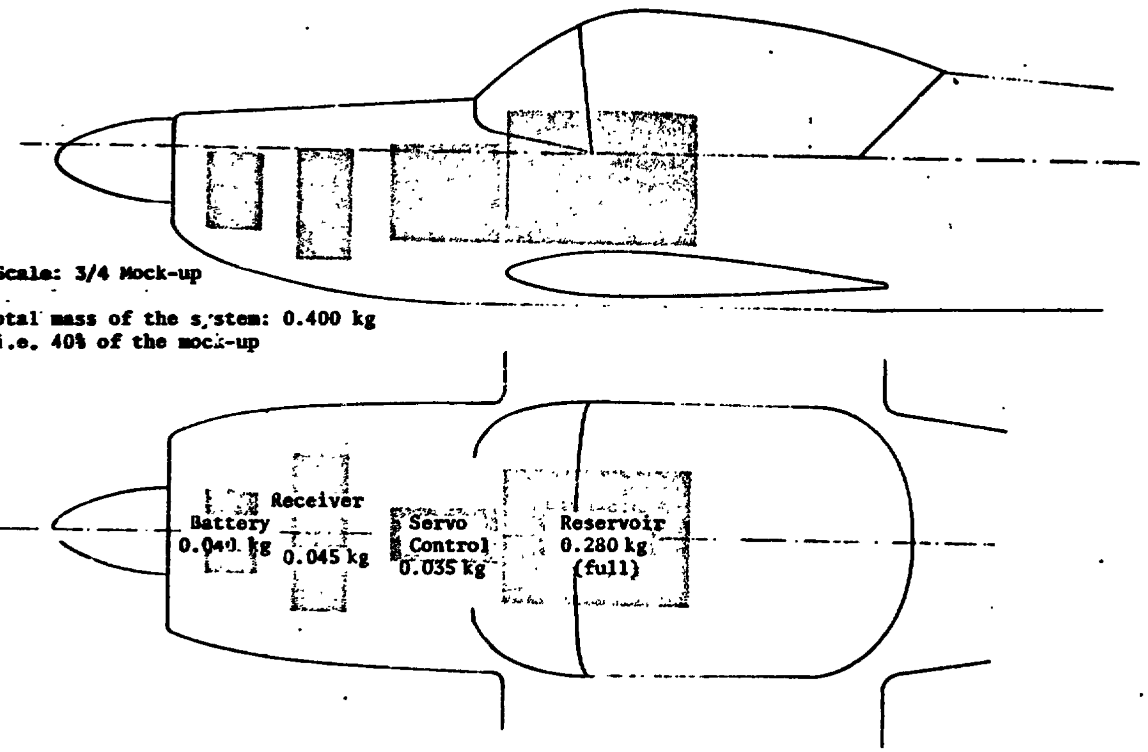
(NASA points out that these observations involve only single-engine planes. Conclusions on the effect of power are very different for multi-engine planes when the power is asymmetric.)

Thus there is good agreement between the NASA findings and those contained in this report.


IMFL
Problem
Designed by
A. Nuzat
Verified by
J. Grourain
Date: 3/21/1977
Plate 1
Installation of the Power System in the CAP 10
Mock-Up
Scale: 3/4 Mock-up
Total mass of the system: 0.360 kg
i.e. 35% of the mock-up
propeller
electric motor
servo control
receiver
battery motor
battery receiver

I M F L	Problem	Designed by	Verified by	Date	Plate . 2
		A. Aubert	L. Dessurow	3/21/1974	

Installation of the Rocket Motor System in the
CAP 10 Mock-Up



Scale: 3/4 Mock-up

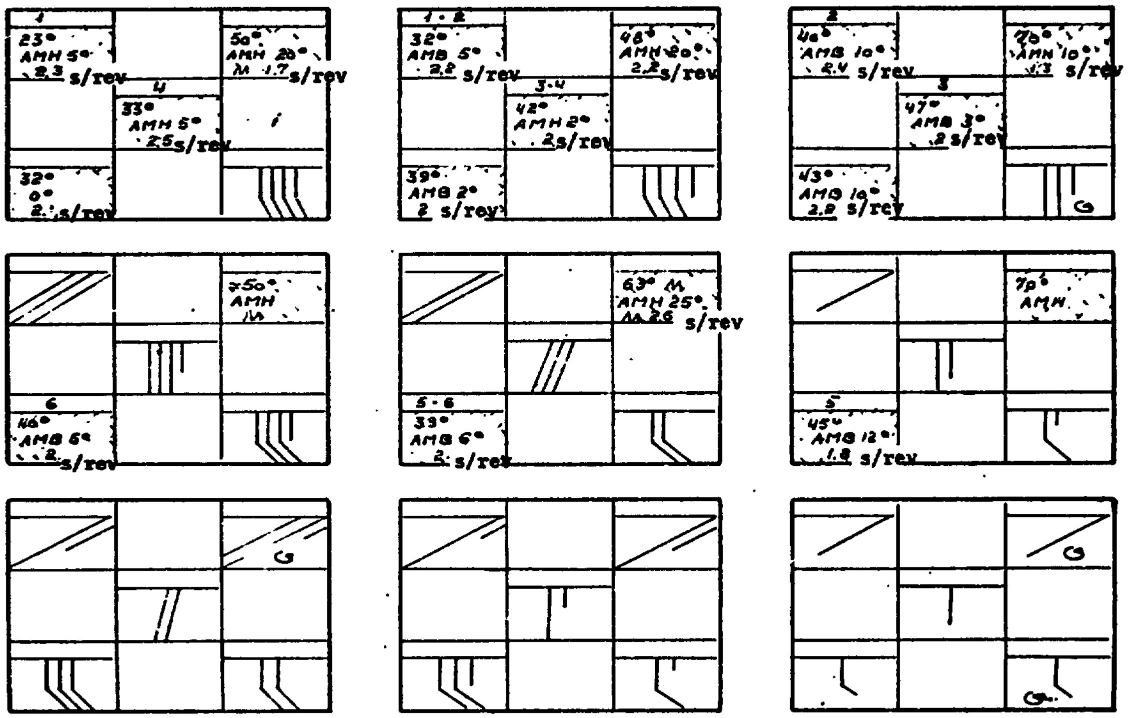
Total mass of the system: 0.400 kg
i.e. 40% of the mock-up

I.M.F.L.	Problem	Designed by	Verified by	Date	Plate 3
	---	L. Beaurain		2/11/77	

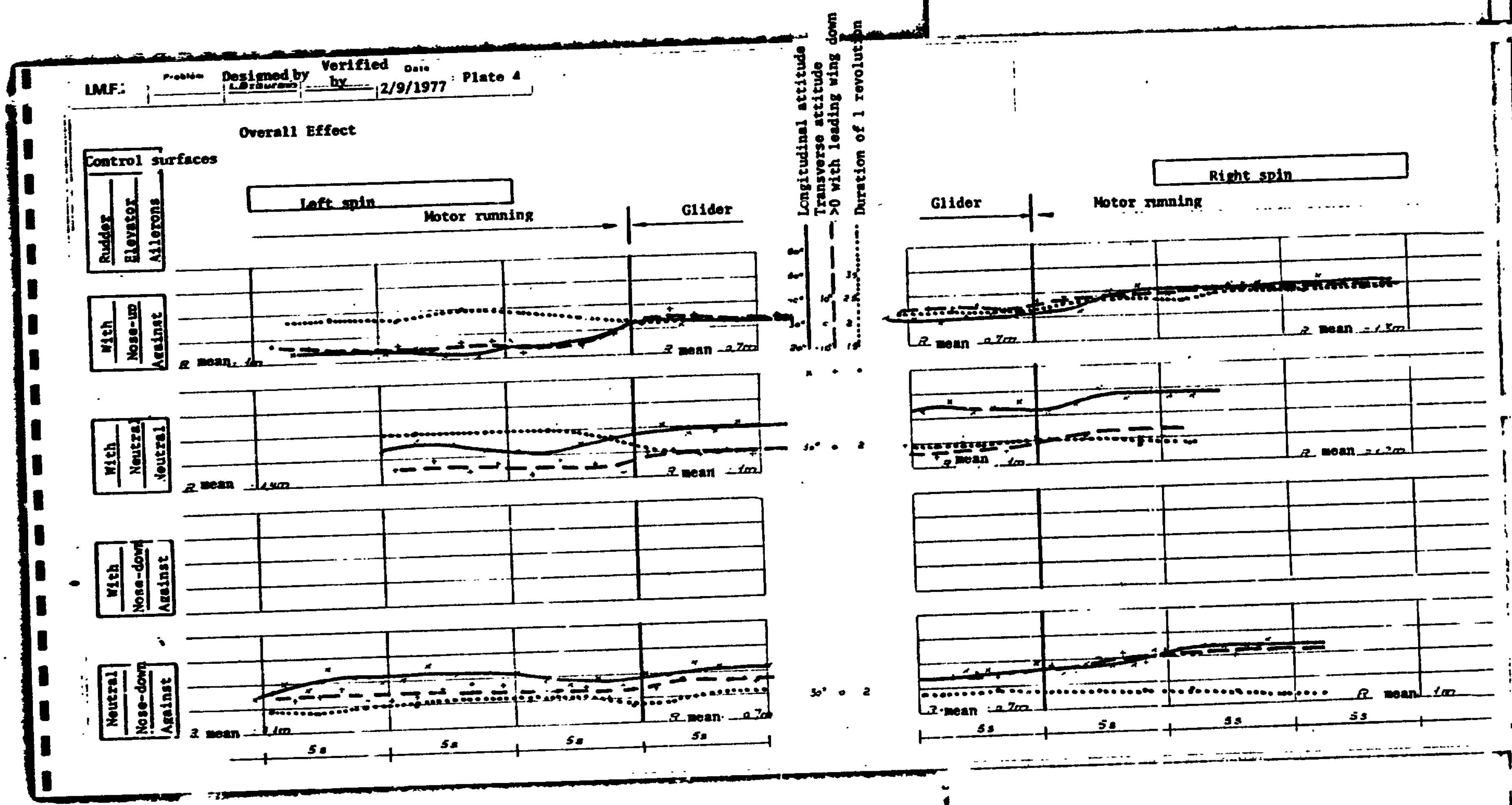
Overall Effect of the Motor

Collected Results

Left spin **Glider** **Right spin**



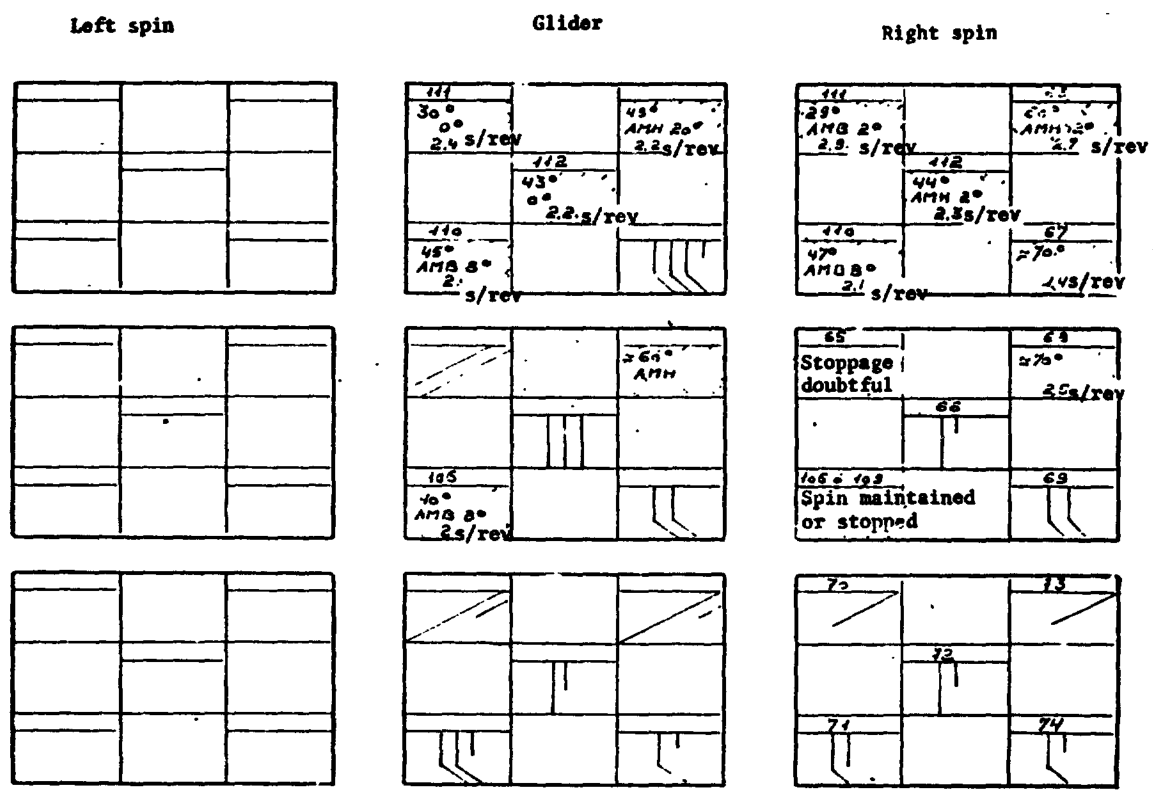
Except for a few control tests, most of the results included in this plate are taken from Plate 4 of I.M.F.L. Report No. 1238/VY.

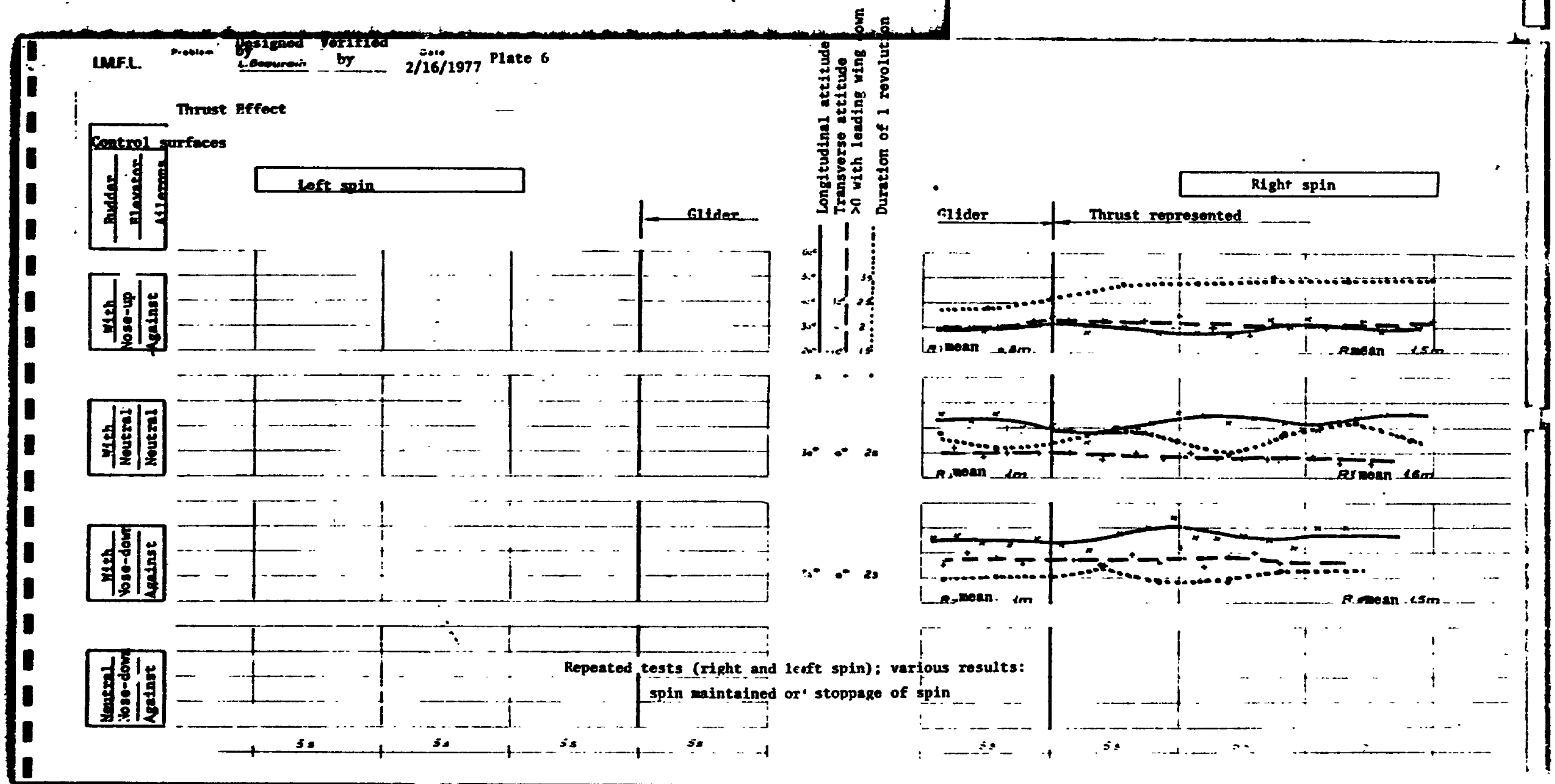

LMF.
Problem
Designed by
L.Brauran
Verified by
Date
2/9/1977
Plate 4
Overall Effect
Control surfaces
Rudder
Elevator
Ailerons
Left spin
Motor running
Glider
Right spin
Longitudinal attitude
Transverse attitude
>0 with leading wing down
Duration of 1 revolution
With
Nose-up
Against
With
Neutral
Neutral
With
Nose-down
Against
Neutral
Nose-down
Against
mean
5s

I.M.F.L.	Problem	Designed by	Verified by	Date 2/15/1977	Plate 5

Thrust Effect

Collected Results



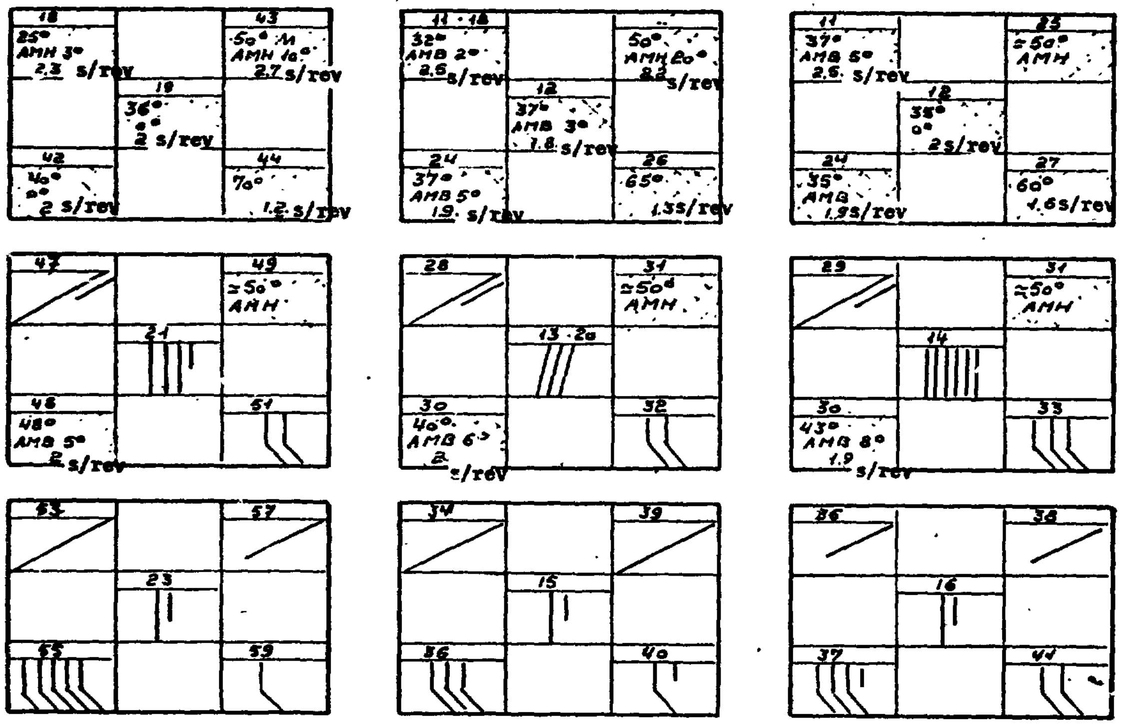

IMFL
Problem
Designed by L.Beaurain
Verified by
Date 2/16/1977
Plate 6
Thrust Effect
Control surfaces
Rudder
Elevator
Ailerons
Left spin
Right spin
Glider
Thrust represented
Longitudinal attitude
Transverse attitude
>0 with leading wing down
Duration of 1 revolution
With Nose-up Against
With Neutral Neutral
With Nose-down Against
Neutral Nose-down Against
R mean
Repeated tests (right and left spin); various results:
spin maintained or stoppage of spin

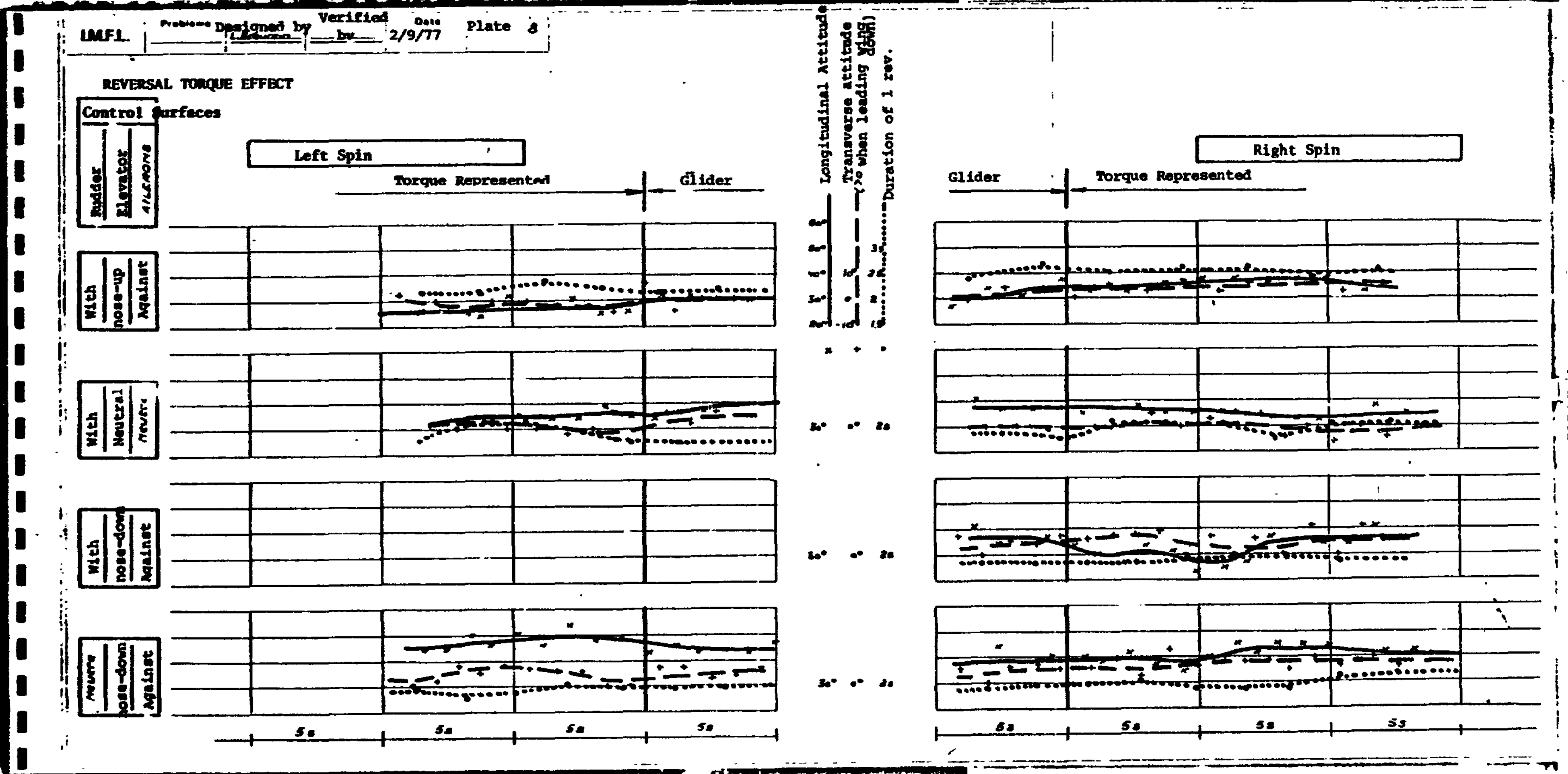
IMFL	Problème	Designed by L.Beaucain	Verified by	Date 2/18/1977	Plate 7

Reversal Torque Effect

Collected results

Left spin — Glider — Right spin




IMFL.
Problems
Designed by
Verified by
Date 2/9/77
Plate 8
REVERSAL TORQUE EFFECT
Control Surfaces
Rudder
Elevator
Ailerons
Left Spin
Torque Represented
Glider
Right Spin
Glider
Torque Represented
With nose-up Against
With Neutral Neutre
With nose-down Against
Neutre nose-down Against
Longitudinal Attitude
Transverse attitude (when leading wing down)
Duration of 1 rev.
5s
5s
5s
5s
5s
5s
5s
5s

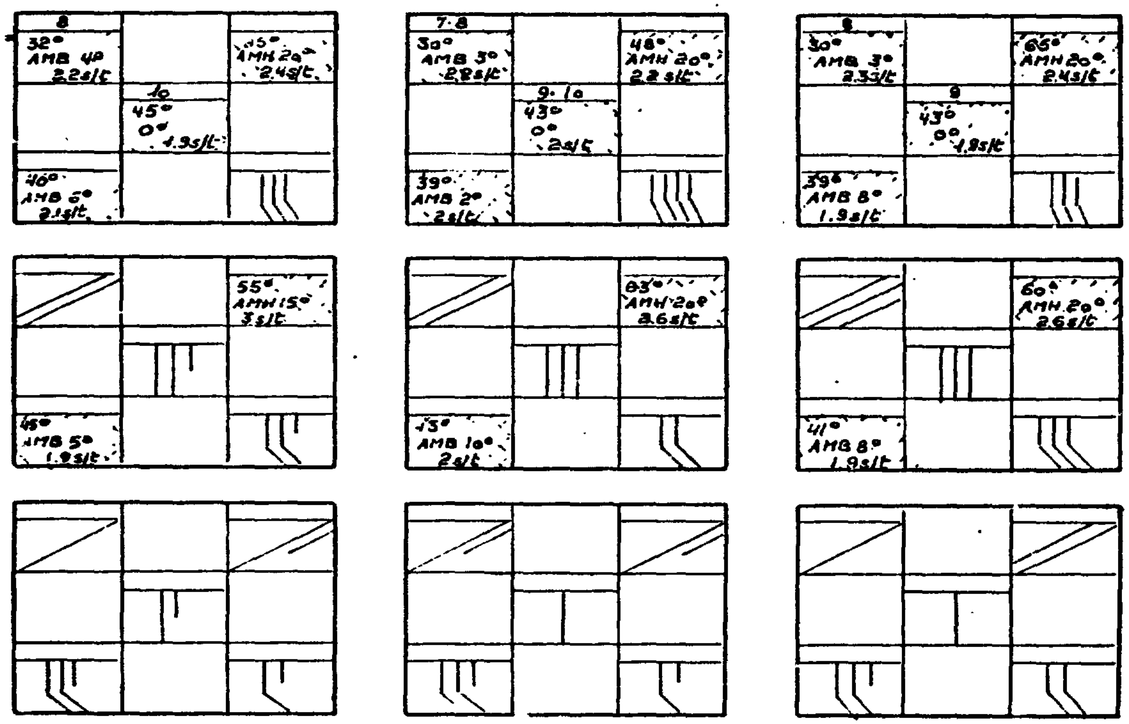
Problème	Designed by	Verified by	Date	Plate
I.M.F.L.	Beaurain		2/11/77	9

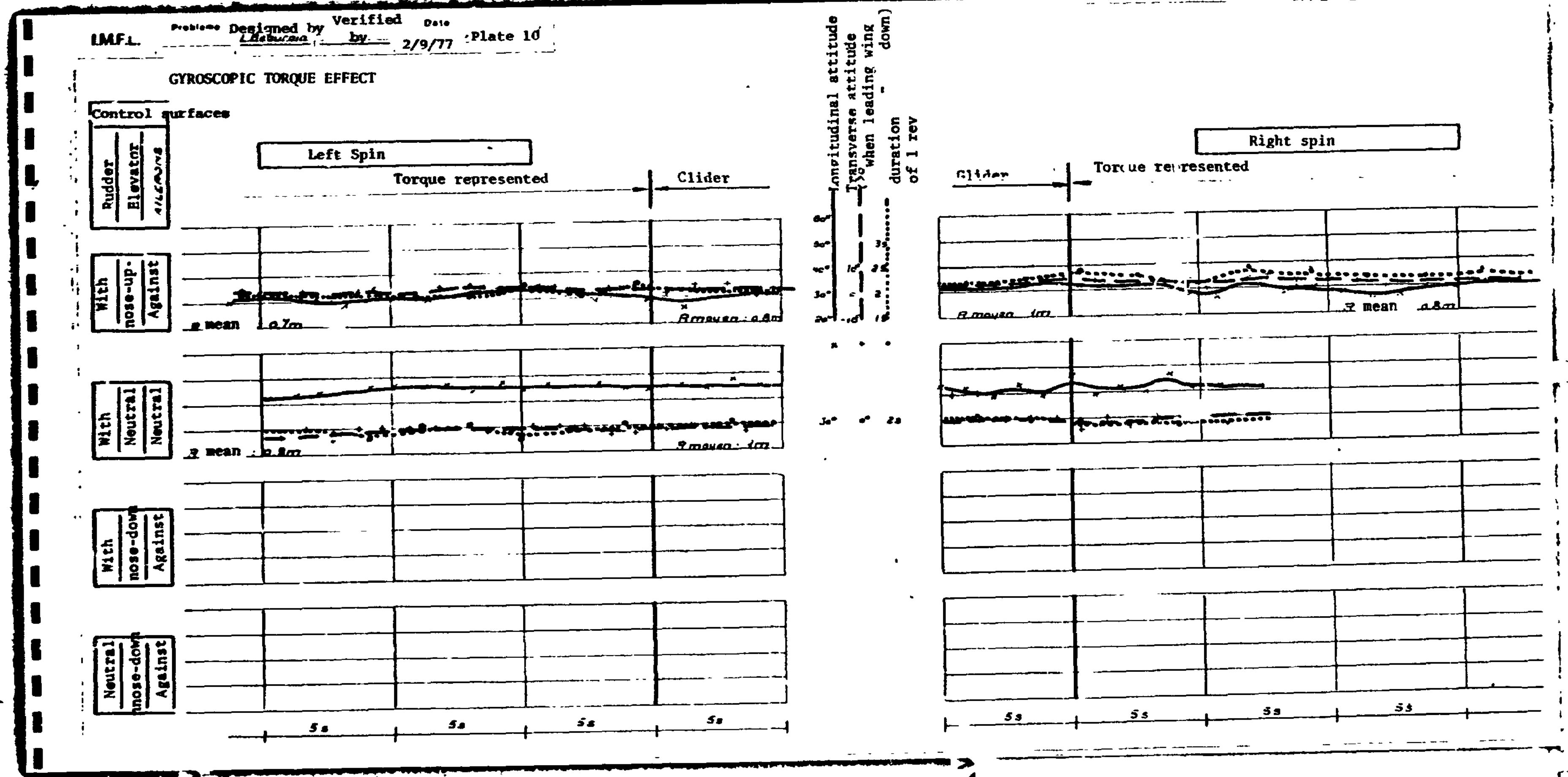
GYROSCOPIC TORQUE EFFECT

COLLECTIVE RESULTS

LEFT SPIN | GLIDER | RIGHT SPIN

note: s/t = sec/rev





I.M.F.L.
Problème
Designed by
Verified by
Date 2/9/77
Plate 10
GYROSCOPIC TORQUE EFFECT
Control surfaces
Rudder
Elevator
Ailerons
With nose-up Against
With Neutral Neutral
With nose-down Against
Neutral nose-down Against
Left Spin
Torque represented
Clider
Right spin
Glider
Torque represented
Longitudinal attitude
Transverse attitude when leading wing down)
duration of 1 rev
mean 0.7m
mean 0.8m
5s

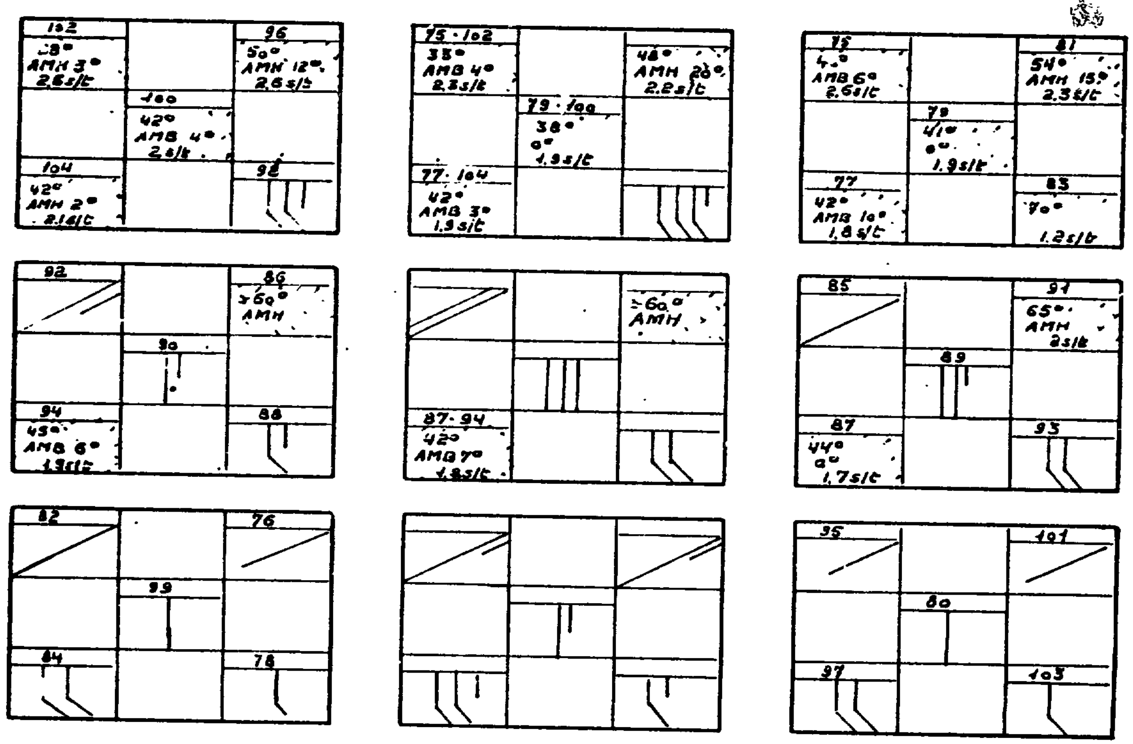
IMFL	Problems	Designed by	Verified by	Date	Plate 11
		L.Aceureh		2/15/77	

OVERALL EFFECT OF INCLINED MOTOR

COLLECTIVE RESULTS

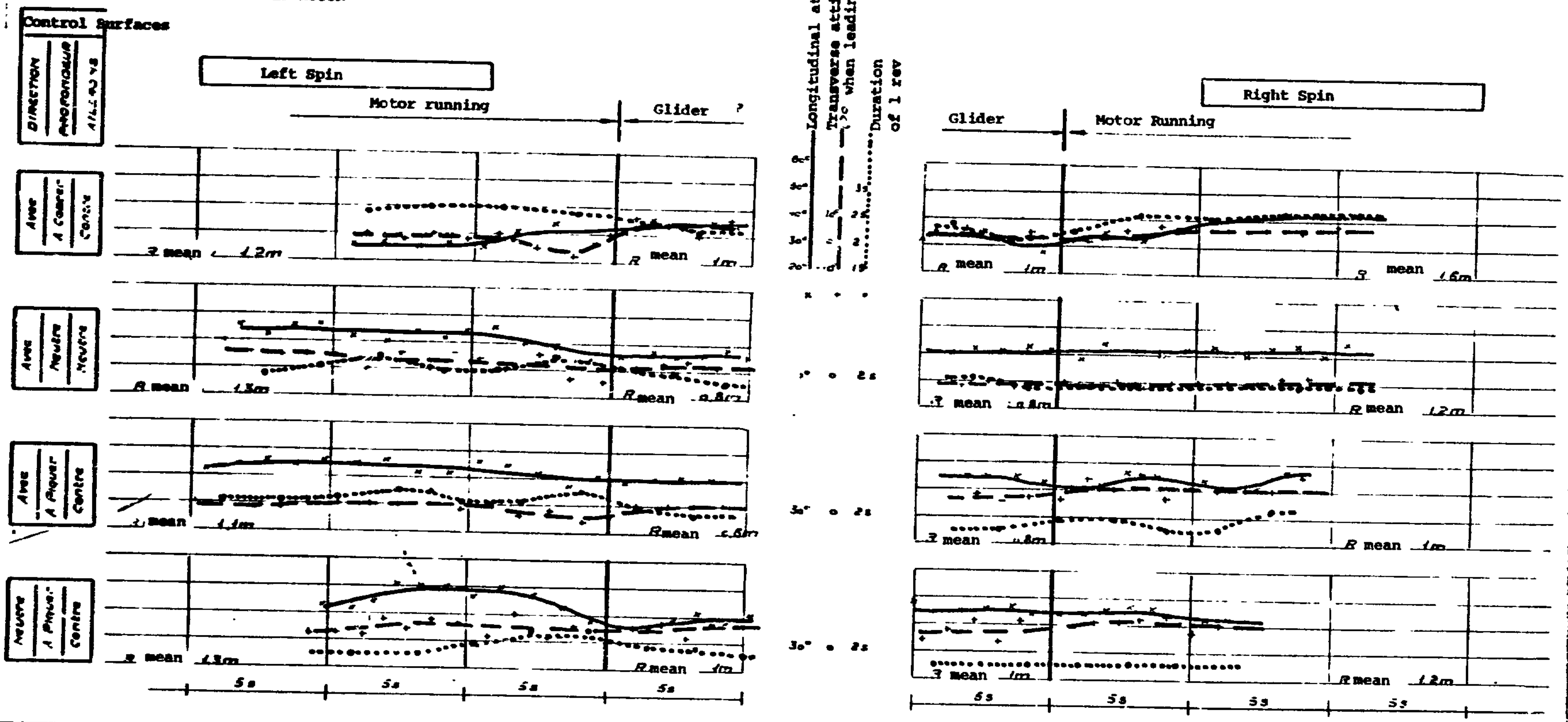
Left Spin Glider Right Spin

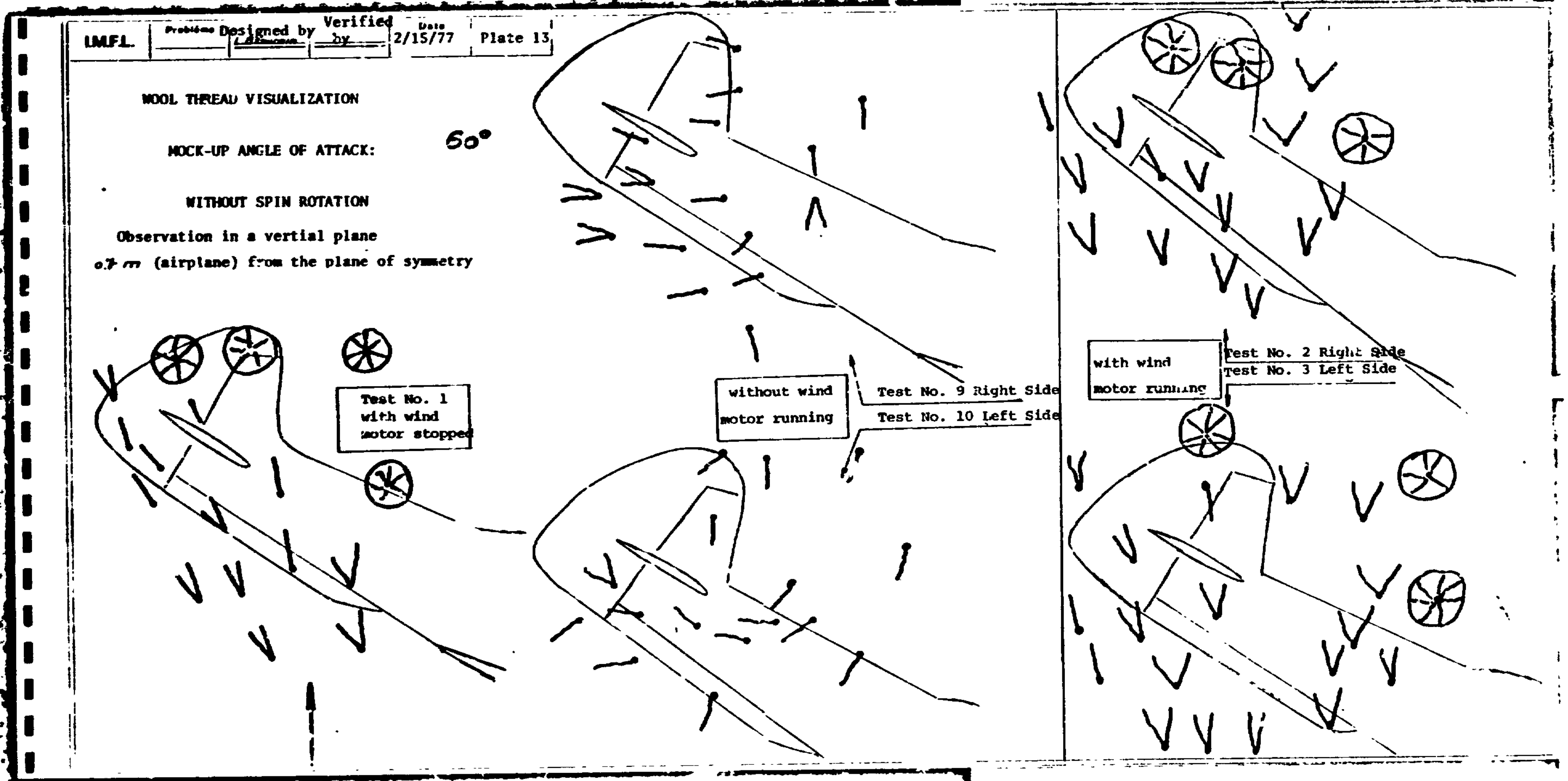
note:
s/t =
sec/rev



IMFL. Designed by L.Beaurain Verified by Date 2/9/77 Plate 12

OVERALL EFFECT OF INCLINED MOTOR




IMFL
Problème
Designed by
Verified by
Date 2/15/77
Plate 13
WOOL THREAD VISUALIZATION
MOCK-UP ANGLE OF ATTACK: 60°
WITHOUT SPIN ROTATION
Observation in a vertial plane
0.7 m (airplane) from the plane of symmetry
Test No. 1
with wind
motor stopped
without wind
motor running
Test No. 9 Right Side
Test No. 10 Left Side
with wind
motor running
Test No. 2 Right Side
Test No. 3 Left Side

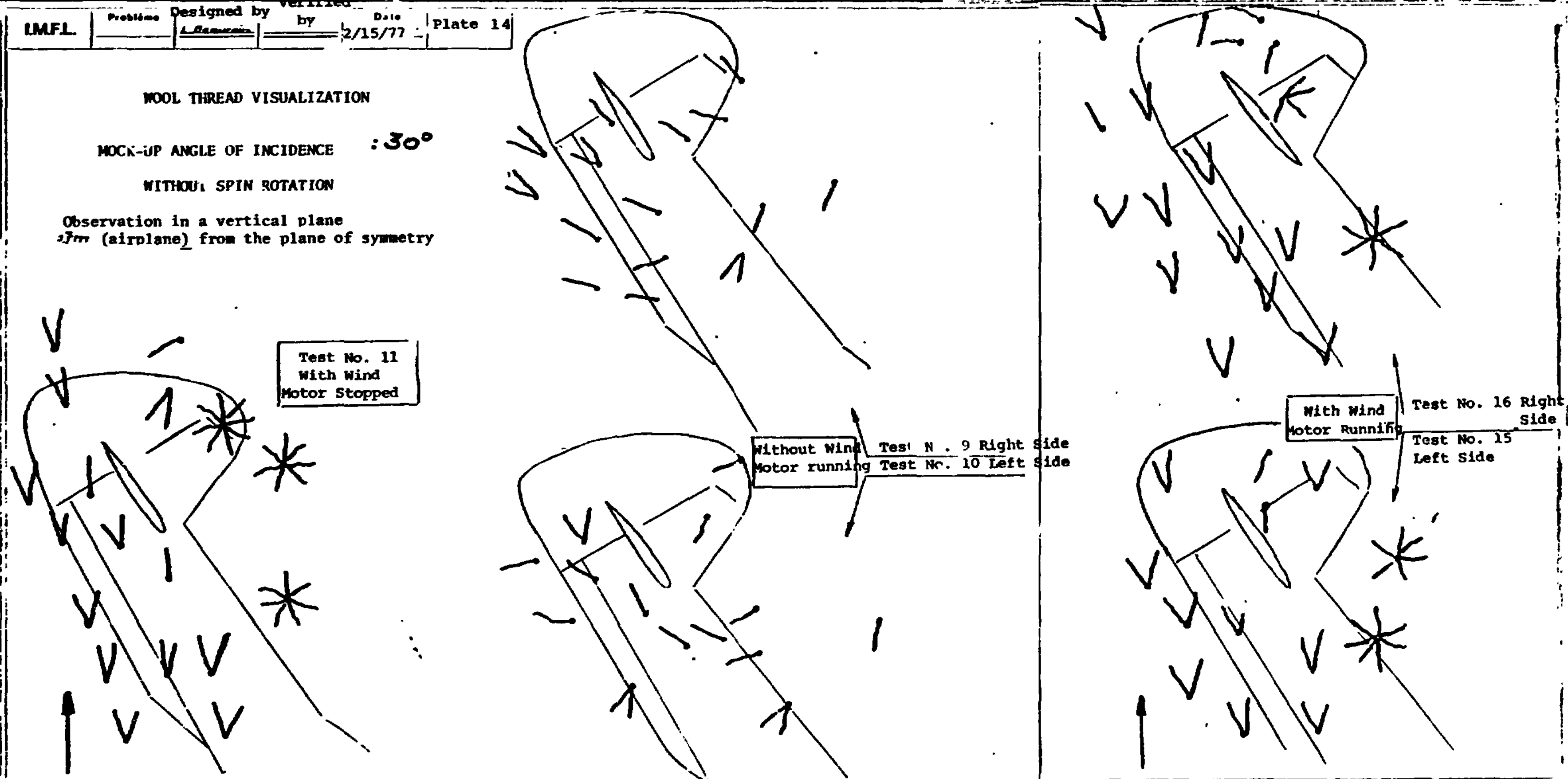
I.M.F.L.	Problème	Designed by	Verified by	Date	Plate 14
		L. Bascurain		2/15/77	

WOOL THREAD VISUALIZATION

MOCK-UP ANGLE OF INCIDENCE : 30°

WITHOUT SPIN ROTATION

Observation in a vertical plane
3 m (airplane) from the plane of symmetry



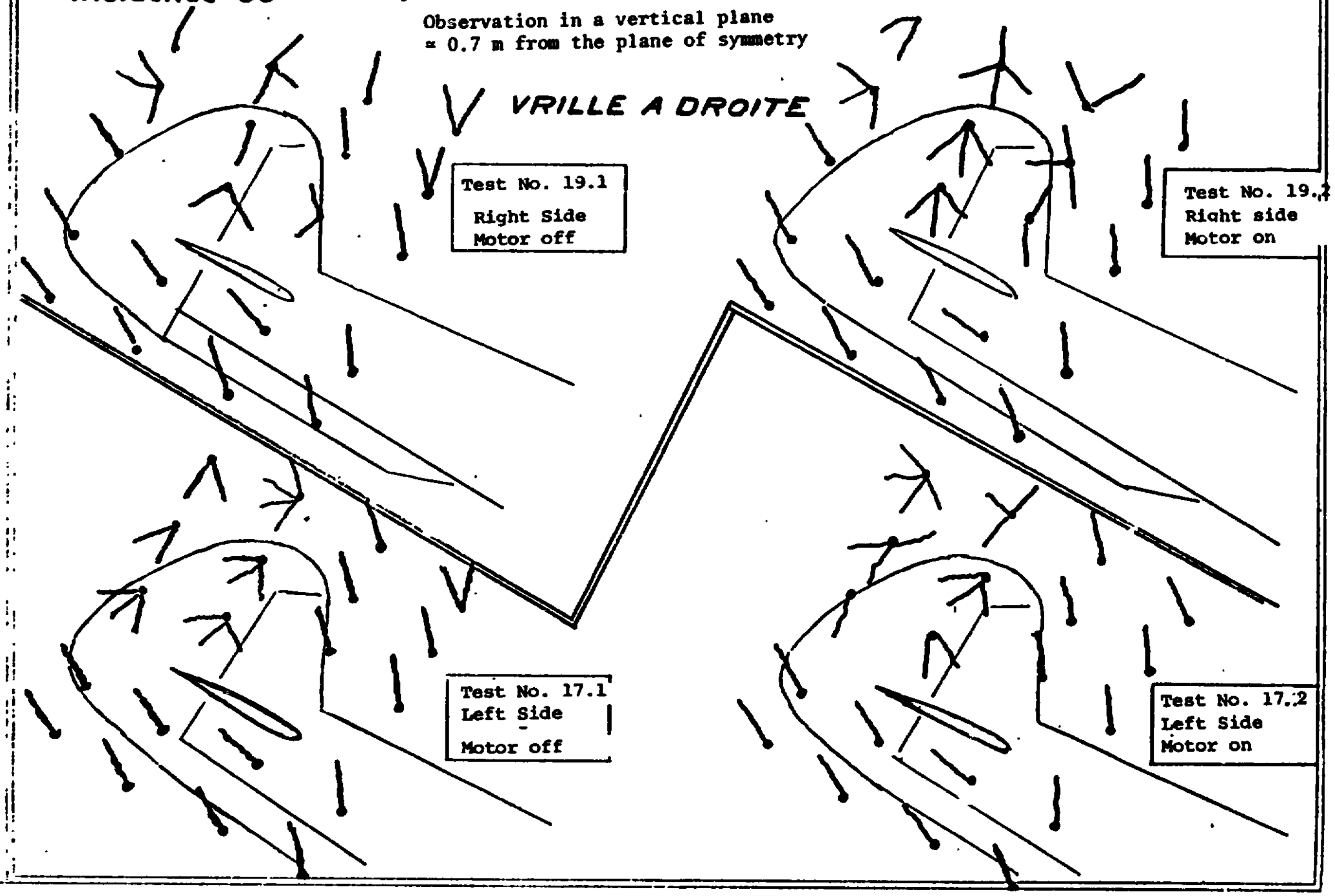
I.M.F.L.	Problème	Designed by L. Beaucain	Verified by	Date 2/15/77	Plate 15

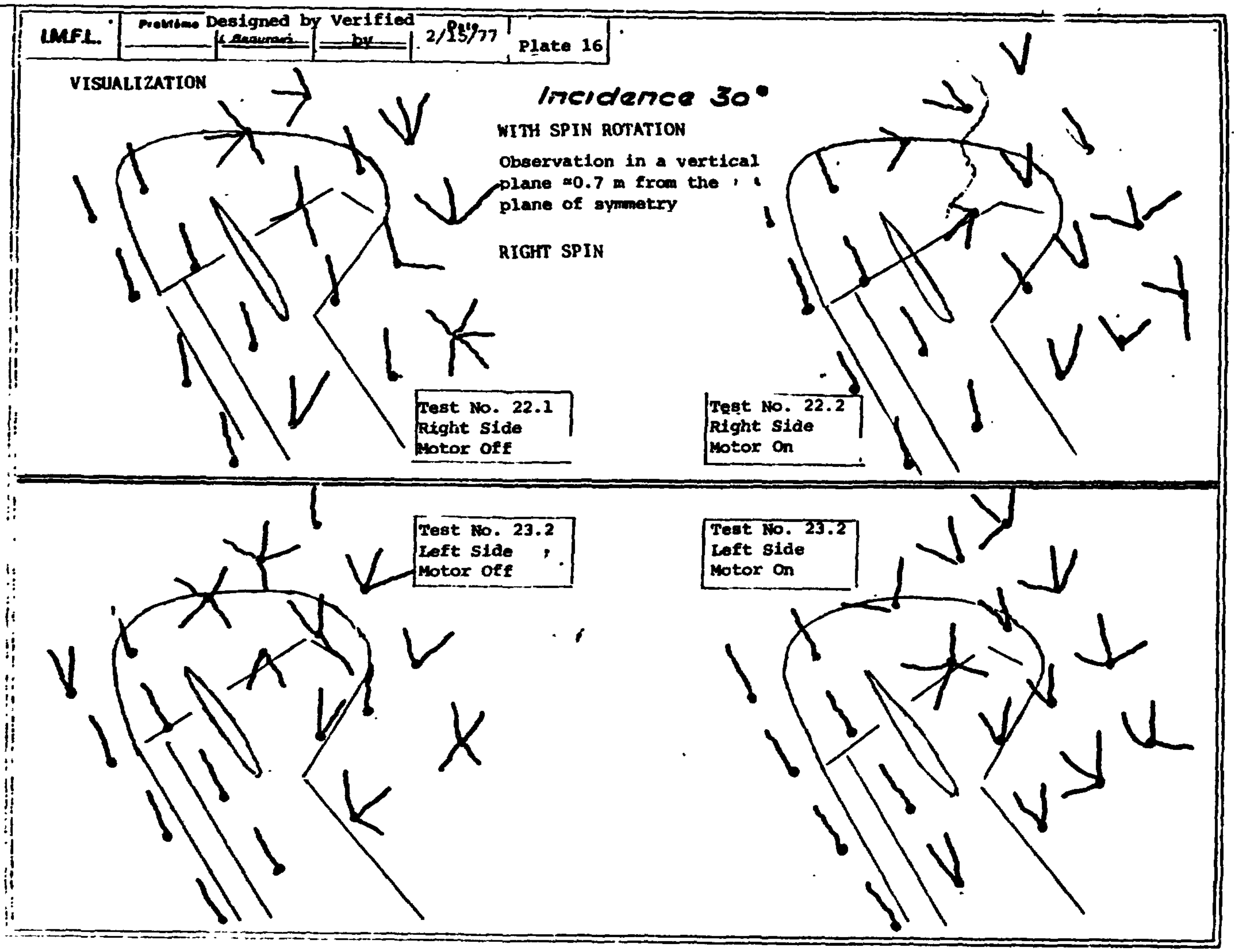
WOOL THREAD VISUALIZATION

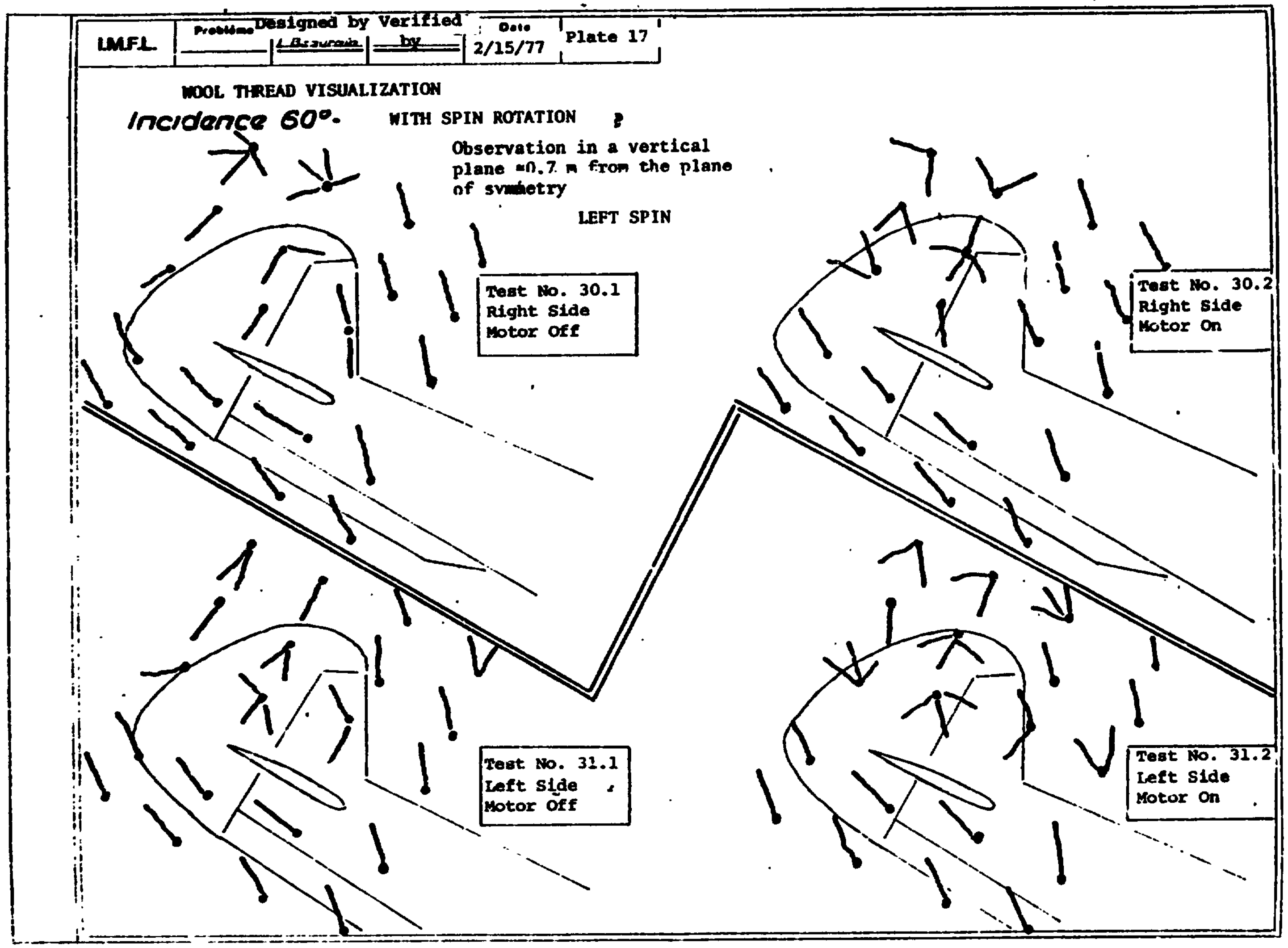
Incidence 60° - With Spin Rotation

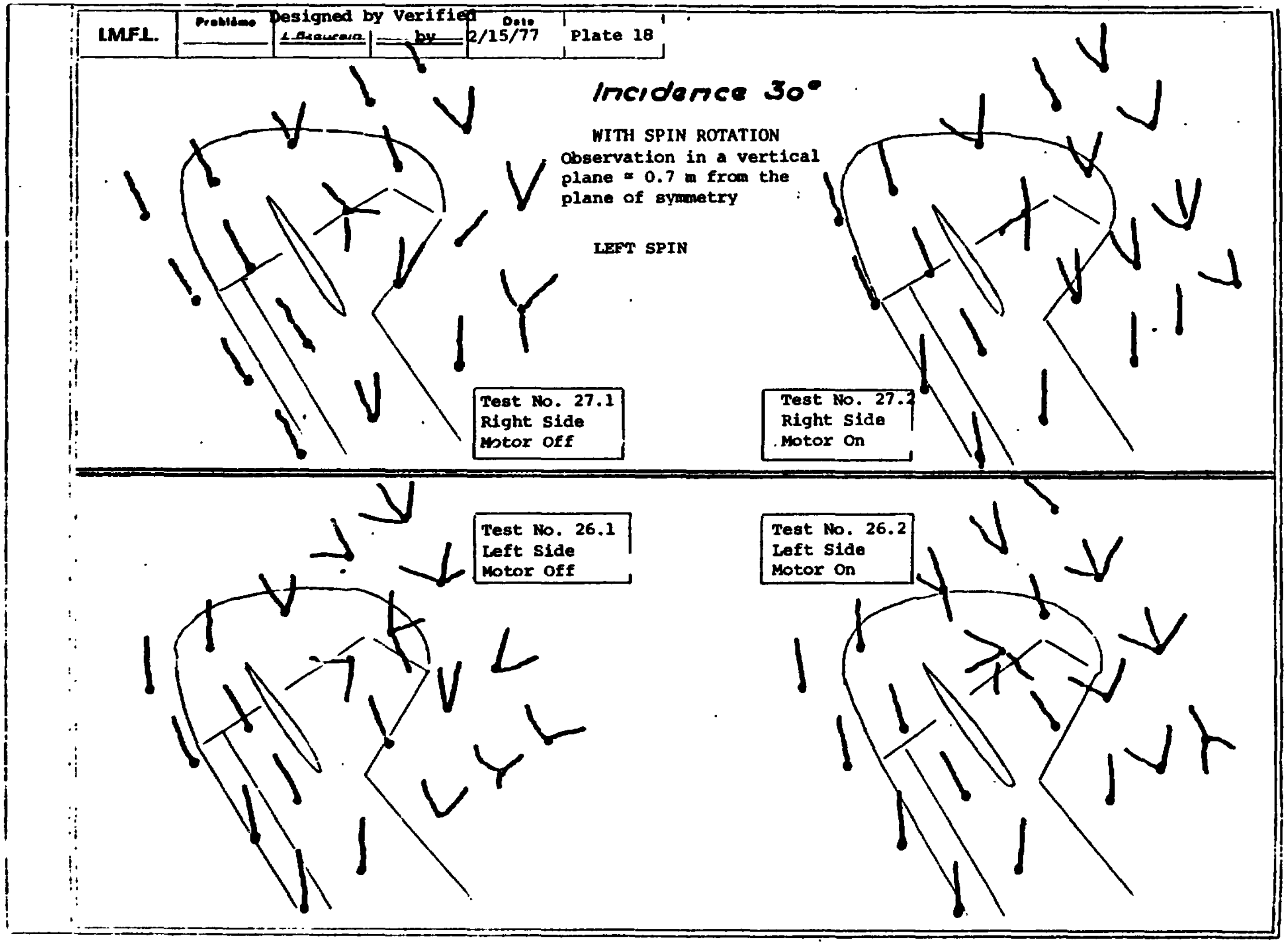
Observation in a vertical plane
≈ 0.7 m from the plane of symmetry

VRILLE A DROITE




IMFL.
Problème
Designed by
Verified by
Date
2/15/77
Plate 16
VISUALIZATION
Incidence 30°
WITH SPIN ROTATION
Observation in a vertical plane ≈0.7 m from the plane of symmetry
RIGHT SPIN
Test No. 22.1
Right Side
Motor Off
Test No. 22.2
Right Side
Motor On
Test No. 23.2
Left Side
Motor Off
Test No. 23.2
Left Side
Motor On


I.M.F.L.
Problème
Designed by
Verified by
Date
2/15/77
Plate 17
WOOL THREAD VISUALIZATION
Incidence 60°.
WITH SPIN ROTATION
Observation in a vertical plane ≈0.7 m from the plane of symmetry
LEFT SPIN
Test No. 30.1
Right Side
Motor Off
Test No. 30.2
Right Side
Motor On
Test No. 31.1
Left Side
Motor Off
Test No. 31.2
Left Side
Motor On


I.M.F.L.
Problème
Designed by
L.Beaurain
Verified by
Date 2/15/77
Plate 18
Incidence 30°
WITH SPIN ROTATION
Observation in a vertical plane ≈ 0.7 m from the plane of symmetry
LEFT SPIN
Test No. 27.1
Right Side
Motor Off
Test No. 27.2
Right Side
Motor On
Test No. 26.1
Left Side
Motor Off
Test No. 26.2
Left Side
Motor On

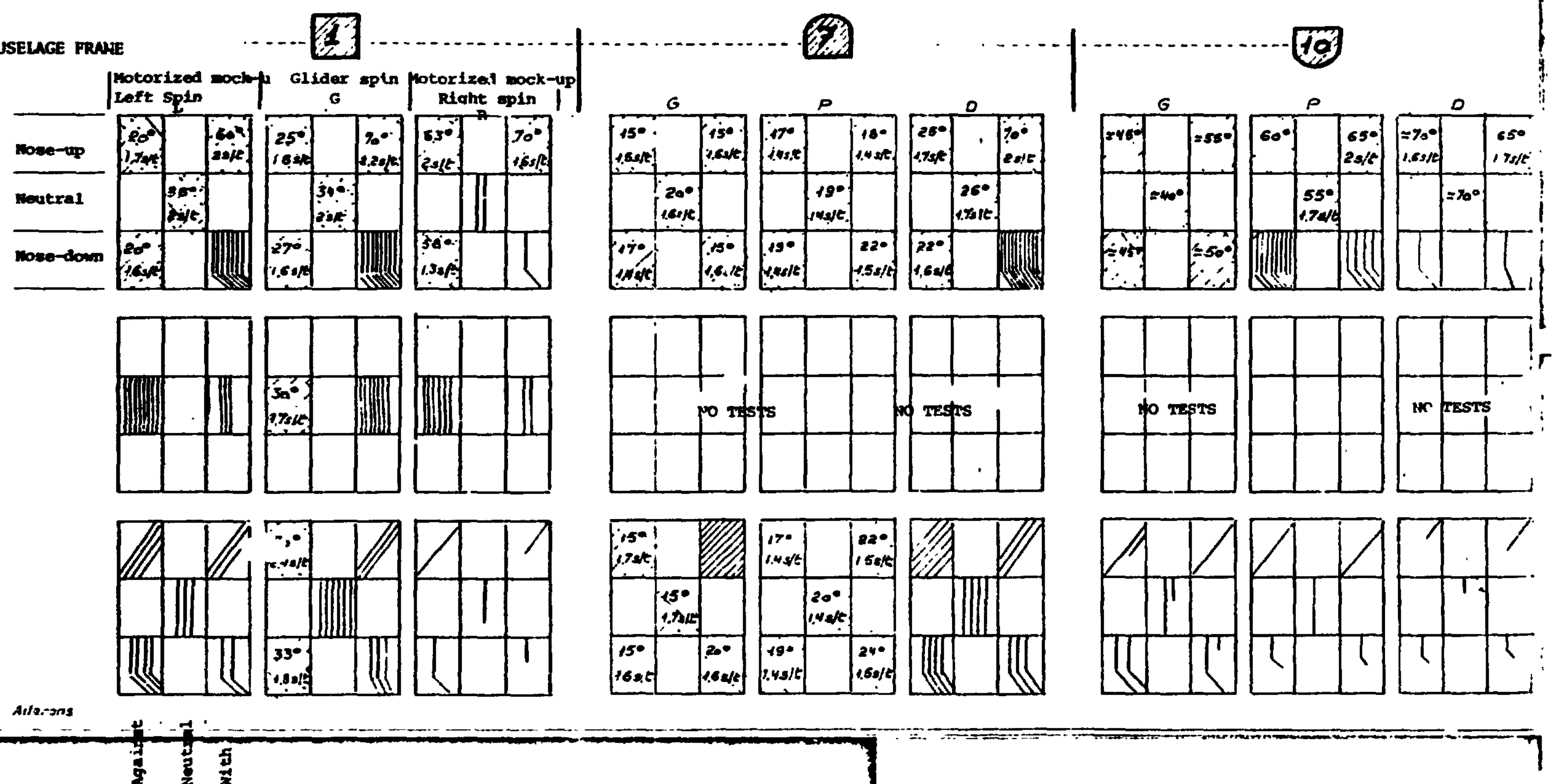
IMFL	Problème	Designed by	Verified by	Date 2/21/77	Plate 19

POWER EFFECT ON VARIOUS
GENERAL MOCK-UPS

AFT FUSELAGE FRAME

The "glider" results included in this Plate are taken from
Pl. 4 of IMFL Report n° 1240 VY

note: s/t = sec/rev



I.M.F.L.	Problème	Designed by	Verified by	Date 2/24/77	Plate 20

EFFECT OF POWER ON SPIN

GENERAL STUDY MOCK-UP
(WITH AND WITHOUT VERTICAL STABILIZER)

AFT FUSELAGE FRAME $\boxed{1}$

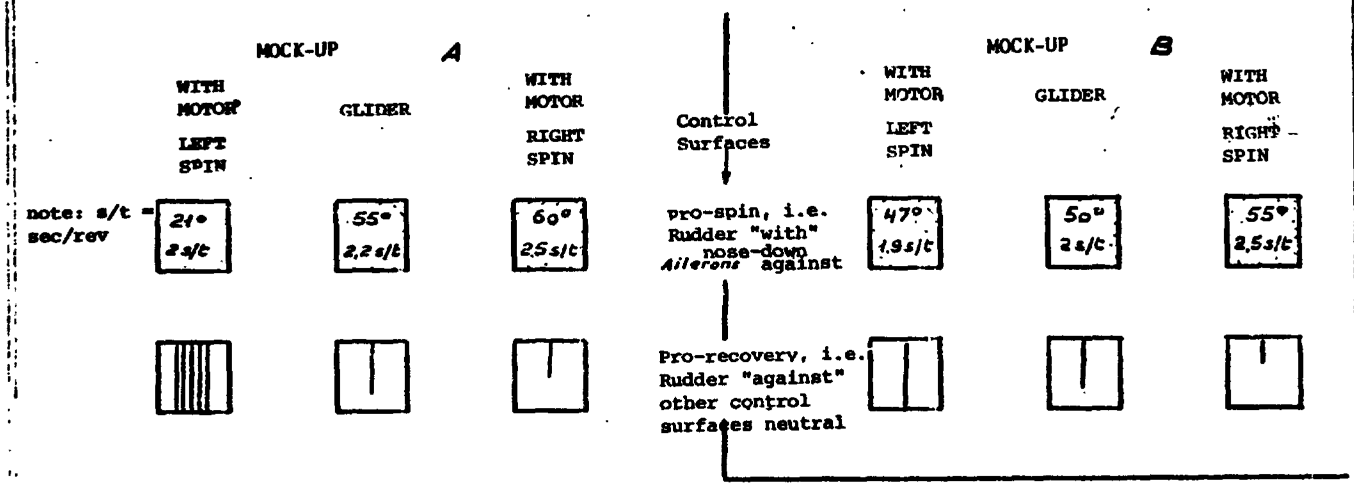
		WITH MOTOR LEFT SPIN	GLIDER	WITH MOTOR RIGHT SPIN
WITH VERTICAL STABILIZER Results taken from P. 9	Ailerons against (pro-spin)		30° 1.7s/t	
	Ailerons with			
WITHOUT VERTICAL STABILIZER	Ailerons against	45° 2s/t	55° 1.9s/t	60° 1.7s/t
	Ailerons with	70°		

For tests with vertical stabilizer: rudder neutral

Column of results taken from Pl. 2 of report 1240 VY

I.M.F.L.	Problème	Designed by	Verified by	Date	Plate 21
				2/24/77	

EFFECT OF POWER ON SPIN MOCK-UPS
OF EXISTING AIRPLANES



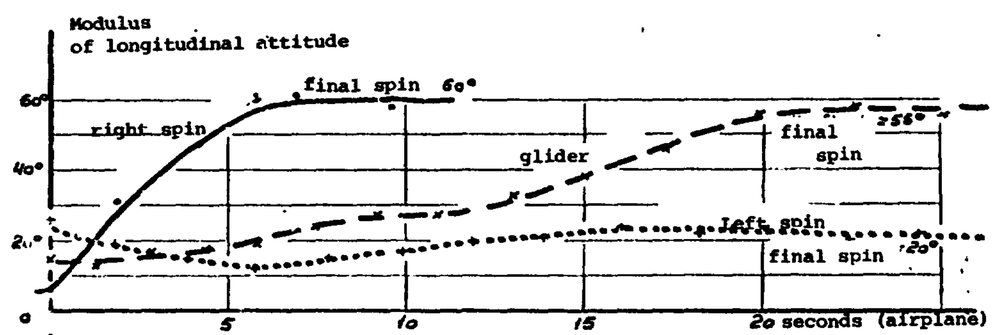
With Mock-up A:

Study of possibilities of maintaining flat, rapid spin

Test conditions:

Cont. surf. pro-spin

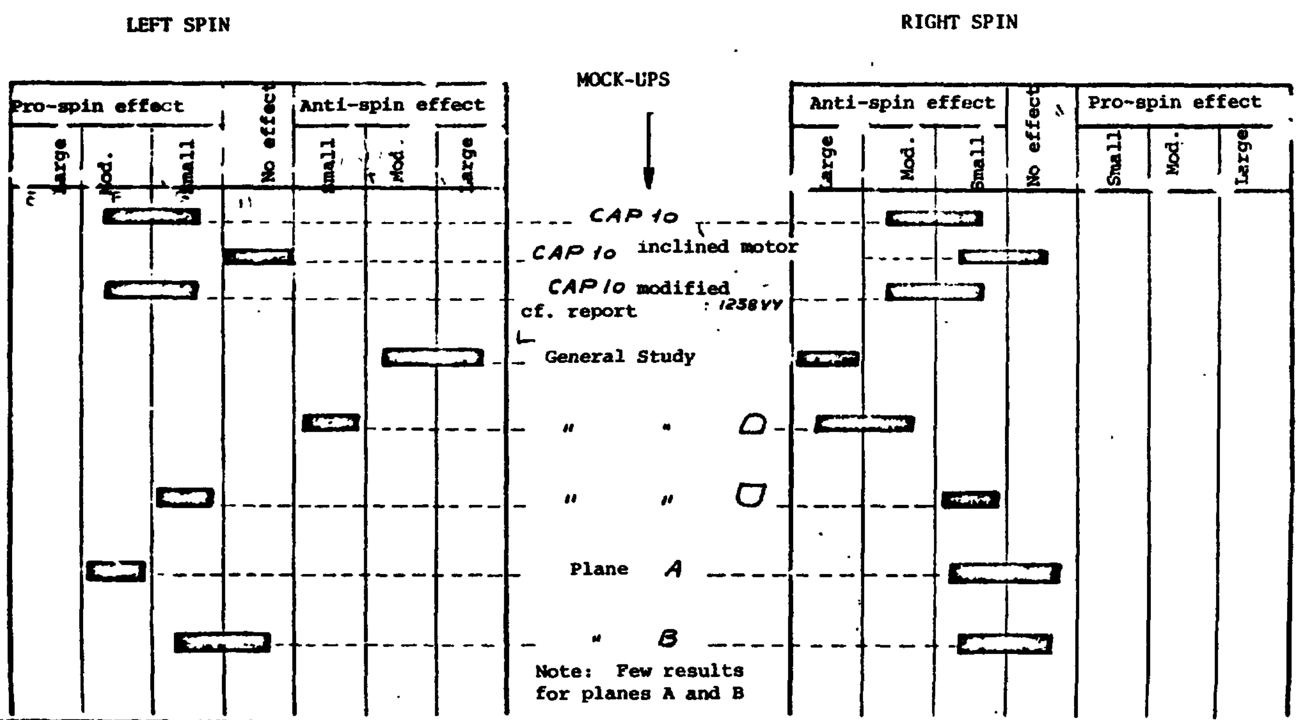
Flat, rapid spin applied to mock-up at launch

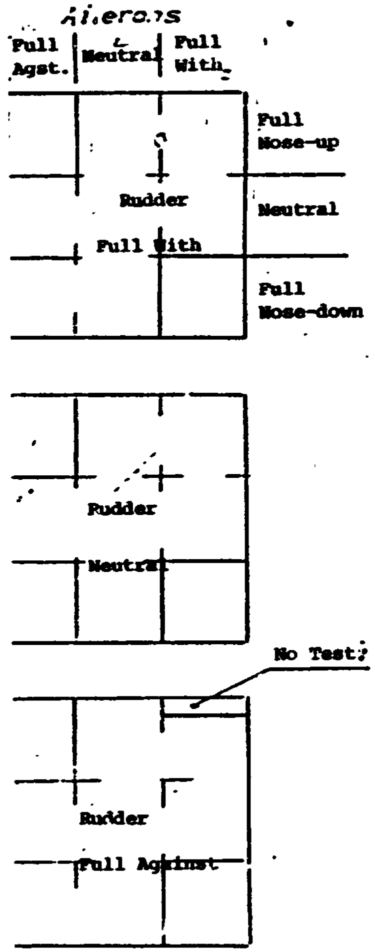


Date [sic] mock-up launched

I.M.F.L.	Problème	Designed by	Verified by	Date	Plate 22
		L. Beaurain		2/24/77	

COLLECTIVE RESULTS FOR
(OVERALL) EFFECT OF POWER
ON VARIOUS MOCK-UPS TESTED





Rudder and ailerons are "with"
[text cut off] are ... for
~~a turn the same . . . as the spin~~

Stationary, i.e. maintained spin

Plate 23

Marginal Phenomena:

a) Irregular spin, possible stoppage; often resembles a spiral

or

b) Very fast. nose-down rotation, possible stoppage, often resembles a vertical roll

M signifies irregular spin

The main characteristics of spin are indicated in a box as follows:

1 - Longitudinal Attitude

2 - Transverse Attitude

Leading Wing Up H

Down B

3 Duration of 1 rev (airplane value)

Recovery from spin:

The number of lines in the box represents the number of revolutions observed until stoppage of the spin, and this the least nose-down spin obtained for the configuration in questions (in the example at left, recovery in 1½ revs.

G sifnifies: belly spin stopped, rotation maintained; examples:

Spiral Recovery

Vertical Roll Recovery

Verticals Rolls Then Back Spin

Oblique recovery: Model dives but still does not attain the vertical (often with control col. back)

Vertical fuselage recovery: (often obtained with control column in neutral position)

Vertical recovery followed by back transition (always obtained with control column forward)

Note: in wind tunnel tests the remain deflected for recovery until the end of the test and thus beyond the stoppage of the spin; this explains the adverse effect on the quality of the recovery [illegible] back transition